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CAST-STEEL ANCHOR CHAIN

By A. E. Crockett*

To you and to the speaker a great privilege has been given; that of living in the greatest period of the world's history. The wildest dream of a few decades ago is to-day a reality; the "impossible" is accomplished, not in one thing only, but many products bear witness to this fact.

To bring to your ever-receptive minds and to insert in the permanent records of our Society data showing one modern accomplishment, the speaker readily accepted the invitation of the chairman of the Publication Committee—Mr. Danforth—to talk to you for a time on cast-steel anchor chain.

As the basis of the experimental work on cast-steel anchor chain was wrought-iron anchor chain, a brief summary relative to this product will first be given.

Practically all stud-link anchor chain, from the beginning of the production of this product, has been made from wrought-iron, though of recent years the use of basic open-hearth steel has found some favor. The tensile strength of the bars out of which the chain is fabricated, however, is practically the same; namely, 48 000 to 52 000 pounds to the square inch. To produce this class of chain one of the following three methods is used:

1. Hand-made; that is, bars cut into a prescribed length for a single link; heated, formed and welded into chain by the chain-maker and his helpers.

2. Machine-made; bars wound into spirals, each convolute severed into single links, heated and welded between dies in a belt-driven hammer.

3. Machine-made; bars cut as for hand-made chain, links formed in a bulldozer, heated, welded under a steam-hammer, and finished between dies that completely cover the entire link, thus shaping it perfectly.

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The last process, however, is used only to a limited extent, owing to the cost of production.

Wrought-iron or steel chain made under either of these processes is required to meet the following specifications in proof stress and breaking stress for the sizes enumerated:

Size	Proof stress	Breaking stress
1⅜"	76 120 lbs.	114 240 lbs.
2"	161 280 lbs.	225 792 lbs.
2¼"	204 120 lbs.	285 600 lbs.
2⅞"	308 224 lbs.	431 480 lbs.

I mention these sizes only, as they are the ones that will be dealt with in this talk.

In past years the making of cast chain has received some attention, but as far as the writer has been able to learn, this chain has not been produced commercially. In fact, whenever this method of producing chain was brought to the attention of a practical chain manufacturer, the subject was lightly treated and labeled "impossible." However, as "necessity is the mother of invention", when in August, 1917, the shortage of anchor chain was accidentally brought to the attention of the Ship Welding Subcommittee of the General Engineering Committee of the Council of National Defense, Mr. W. L. Merrill, of the General Electric Company, Chairman of this Committee, undertook a study of anchor chain production. On September 13, 1917, the General Purchasing Officer of the Emergency Fleet Corporation communicated with Professor Comfort Adams, Chairman of the General Engineering Committee above referred to, setting forth the fact that the productive capacity of anchor chain in the United States was inadequate, and requested recommendations for overcoming this shortage.

Mr. Merrill at that time had under consideration several methods for producing chain; namely:

1. Straight electric welding.
2. Drop forging of alternate links and electric welding of connecting links.
3. Cast-steel chain.

The last of these processes was considered most promising by him, and on this basis the General Electric Company entered

upon a series of experiments and tests to prove or disprove the conclusions Mr. Merrill had reached.

This company in the beginning assumed that wrought-iron had always been a satisfactory material and that there would be a more sympathetic interest in a chain having some approximation to the qualities of wrought-iron chain than in one of which the physical characteristics were radically different from those of the material commonly used. To this end the company set out to make a practical composition of cast-steel which, while it was easily cast into the necessary forms and sizes, would be soft and ductile.

The first attempt to make cast-steel chain used electric-furnace steel, adopting the die-casting process with metal molds.

The product was perfectly sound and of good finish, but it was not found practicable to develop this process for commercial production for the reasons set forth below:

1. It was imperative that the mold be opened at a very critical time, while the metal was congealing. If left for a few seconds longer, the links broke due to the core being solid.

2. If the mold was opened too quickly, the links, being in a plastic state, tended to deform.

They then made a considerable amount of chain using sand molds and cores, experimented with heat treatment, and secured photomicrographs, and eventually secured links which pulled at from 60 to 100 per cent. above wrought-iron chain. The first of these links were tested by the United States Bureau of Standards and some further samples were tested at a later date at the Charleston Navy Yard. In the latter tests six cast-steel links two inches in diameter were used. Three of the links had been annealed at 850 degrees C. and cooled in the furnace, and three links had been heated to 850 degrees C. and quenched in water.

The links were tested in an 800 000-pound, chain-testing machine with the following average results:

Average of 3 links	Breaking strength	Total stretch
Annealed	324 083 lbs.	1 3/16 in.
Quenched	329 750 lbs.	1¼ in.

(*Note.* The breaking test of two-inch wrought-iron chain is 225 792 pounds.)

Before testing, each link was subjected to a proof stress of 145 400 pounds and none of the links showed a measureable elongation. The diameter was slightly less than two inches and the original length was 11 13/16 inches.

Test-bars cut from the same melts and subjected to the same annealing or heat treatment showed the following results:

Average of 3 samples	Tensile strength lbs. per sq. in.	Yield point lbs. per sq. in.	Elongation in 2 in. per cent.	Reduction of area per cent.
Annealed....	74 500	54 000	20.5	28.5
Quenched ...	74 450	55 300	20.8	29.9

All samples broke with 45-degree fracture.

The chemical analyses made from composite drillings taken from the links were:

	Carbon	Manganese	Phos-phorus	Sulfur	Silicon
Annealed links..%	0.32	0.55	0.034	0.025	0.14
Quenched links..%	0.35	0.68	0.027	0.026	0.15

The general conclusions from these tests were that the quenched link was somewhat superior to the annealed link and that the yield points of both were much in excess of that of wrought-iron.

In all these links the stud was cast in.

Following this, a series of comparative percussion and bend tests was carried out on separate links of cast-steel and wrought-iron:

1. The links were dropped from a height of 35 feet on an iron slab.

2. The links were struck on end by a weight of 3300 pounds falling from a height of 43 inches.

(In both of these tests links were tested at normal and at zero temperatures.)

3. The links were supported at their ends and struck in the middle by the same weight and with the same drop as in 2.

The general conclusion from these tests was that they had little relative value, or that they did not duplicate conditions met with in service.

It was then suggested that tests be devised whereby the energy absorbed in breaking the links by a sudden blow would be

measured. A machine was built, and arrangements made to do this by the use of the oscillograph, but great difficulty was experienced in obtaining satisfactory means of holding the couplets of chain and the separate links, and no really quantitative results were obtained.

The foregoing practically sets forth the results of the work done by the General Electric Company, which made many heats, the average of which showed the results above indicated—namely, 35 per cent. reduction and 21 per cent. elongation—and also showed that the metal was not radically different from wrought-iron in its tensile properties; and the approach to the physical characteristics of wrought-iron is the more satisfactory when one considers that it is cast-steel of which the grain refinement is simply the result of heat treatment. Chain made from such steel would be stronger than wrought-iron chain; that is, under either a static load or impact a higher stress would be required to deform it, while when tested to destruction it would be deformed nearly, if not quite, as much as wrought-iron chain when fracture finally occurred. Thus the General Electric Company felt it had offered a good solution of the problem of producing a cast chain stronger than, and as tough as, the wrought chain universally used.

It was at this period that the National Malleable Castings Company was invited to participate in the experimental development.

This company was particularly well qualified to undertake the work, by reason of extended experience in making electric steel and possession of the necessary equipment in the plant at Sharon, Pa. A number of years ago the company's attention had been directed to the large breakage of car coupler knuckles and, to overcome this, painstaking study and experiment had been undertaken, resulting in a product that successfully withstands the severe punishment of jerking and jamming of the heavily loaded train, and the company felt that its "Naco" steel would meet the somewhat similar rough usage of anchor chain.

Instead of following precedent in imitating wrought-iron, the company adopted a superior material, as will be shown later, and gave attention chiefly to what was considered the real diffi-

culty—that of developing a suitable foundry method of producing chain links in sand molds and uniting them into continuous lengths of chain. This investigation resulted in a number of entirely successful equipments for making the molds, four of which are shown in Fig. 1–14.

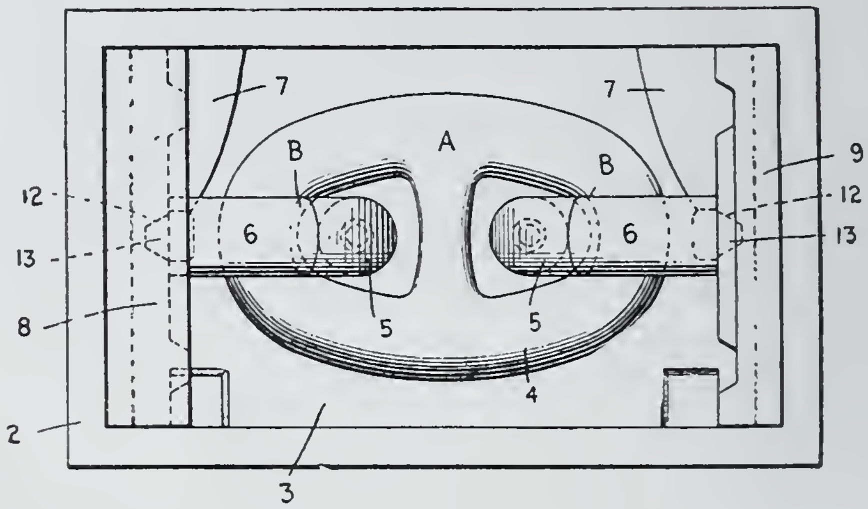

Fig. 1. First Method of Making Molds.

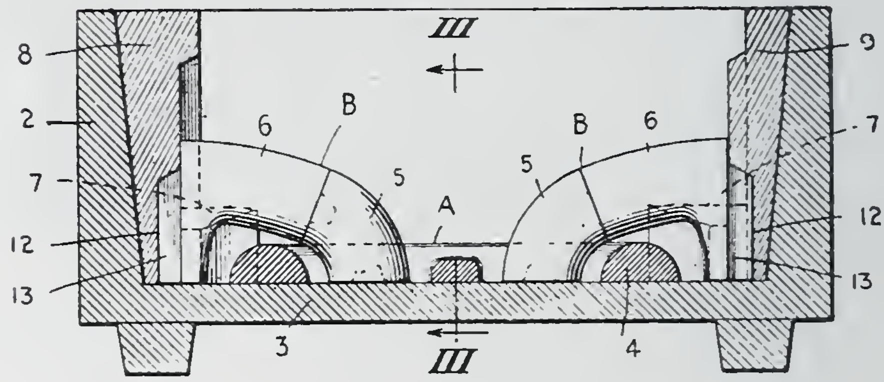

Fig. 2. First Method of Making Molds.

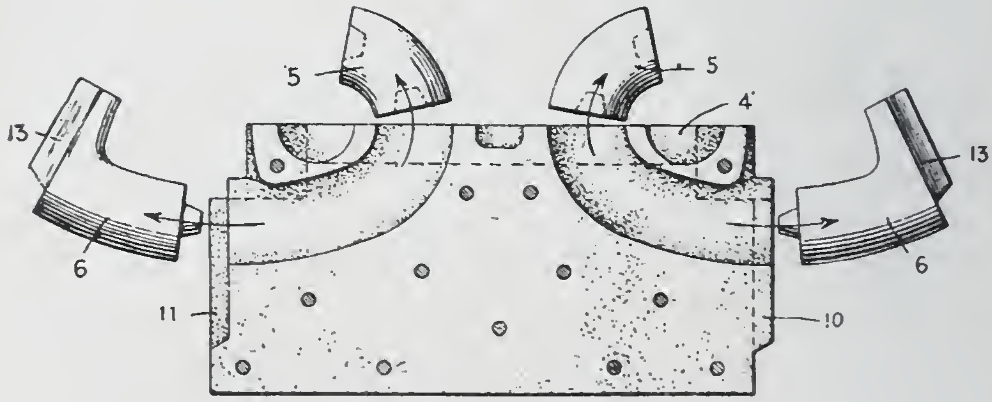

Fig. 3. First Method of Making Molds.

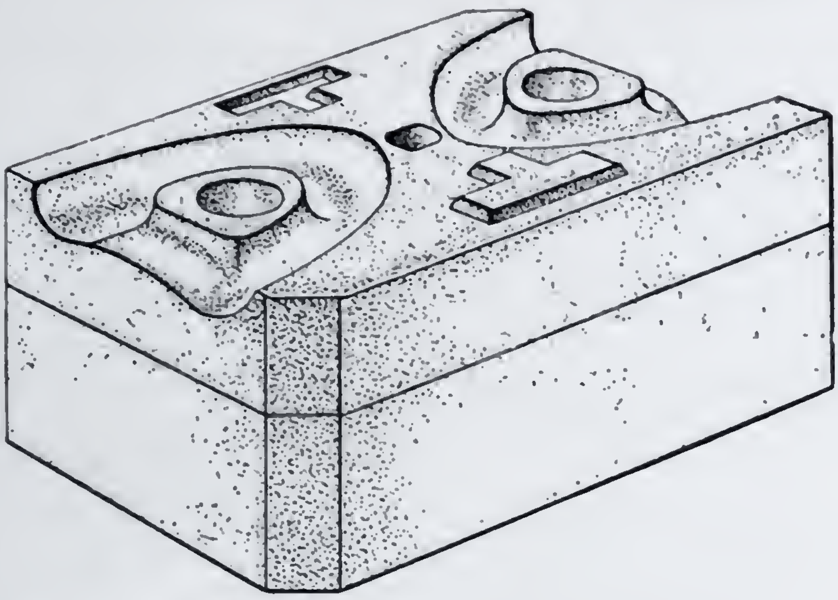

Fig. 4. First Method of Making Molds.

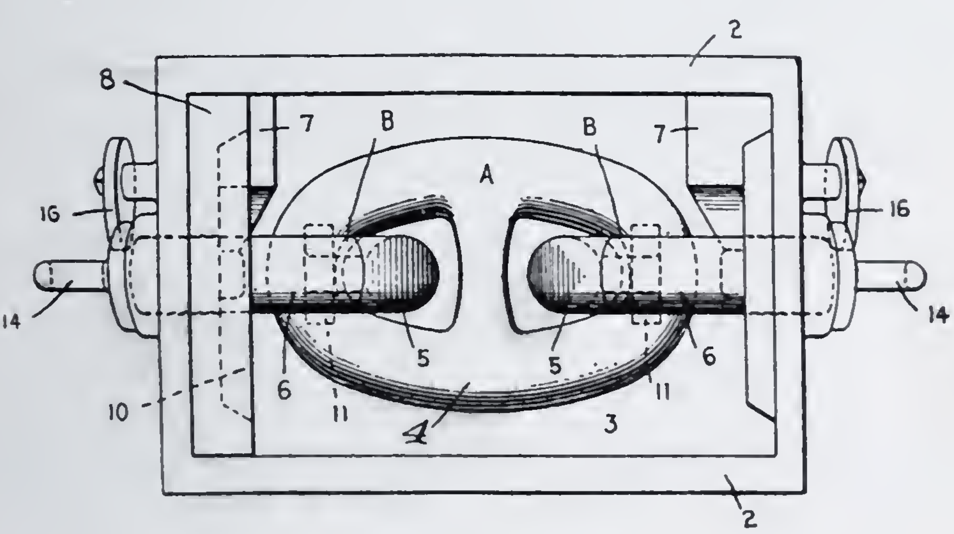

Fig. 5. Second Method of Making Molds.

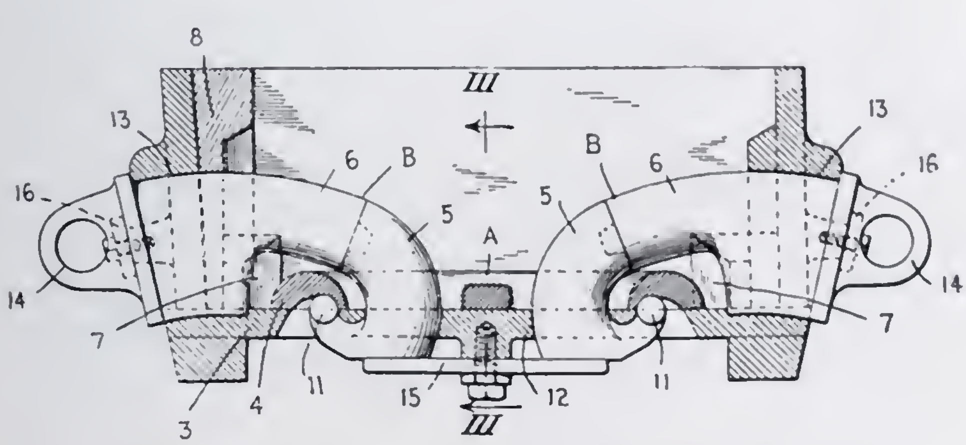

Fig. 6. Second Method of Making Molds.

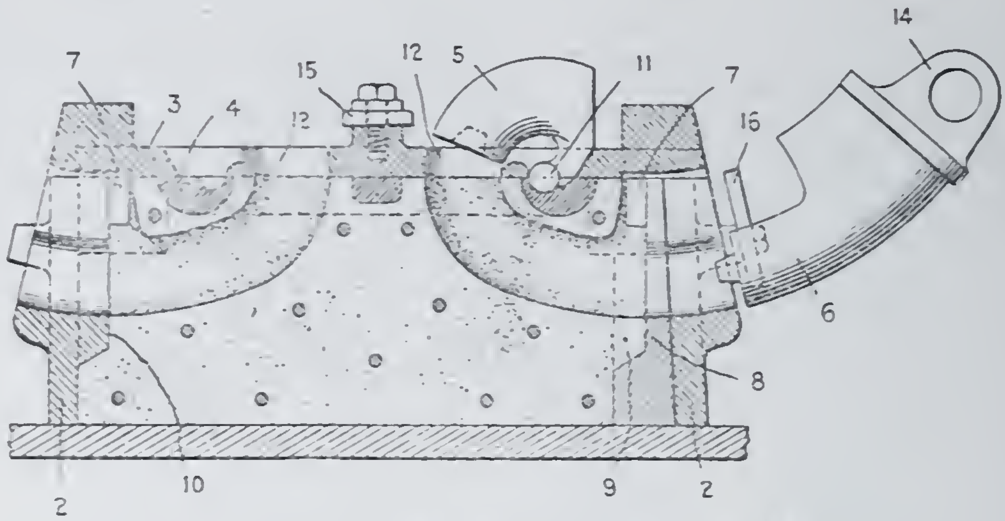

Fig. 7. Second Method of Making Molds.

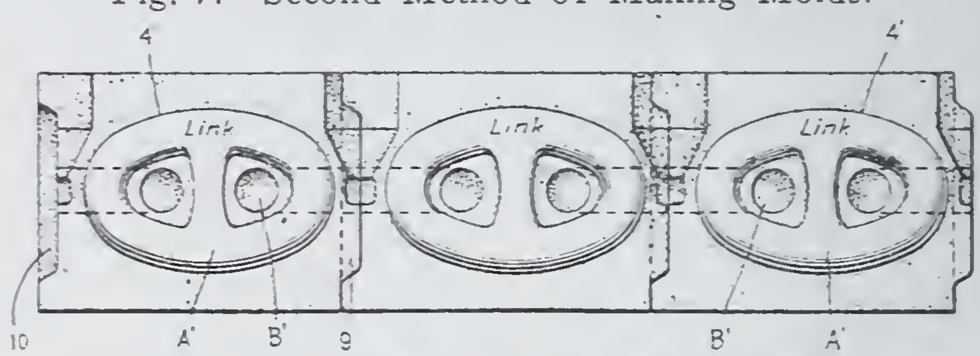

Fig. 8. Second Method of Making Molds.

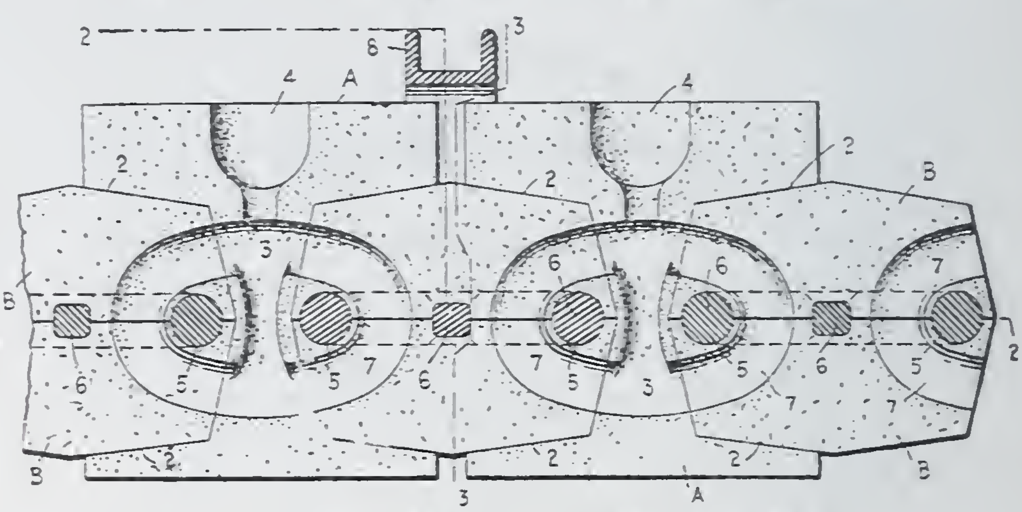

Fig. 9. Third Method of Making Molds.

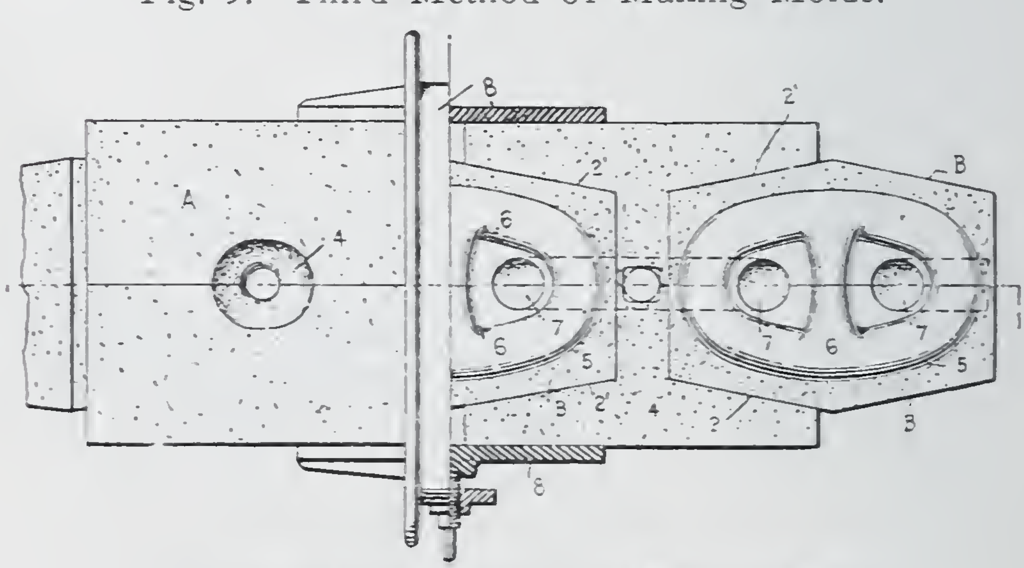

Fig. 10. Third Method of Making Molds.

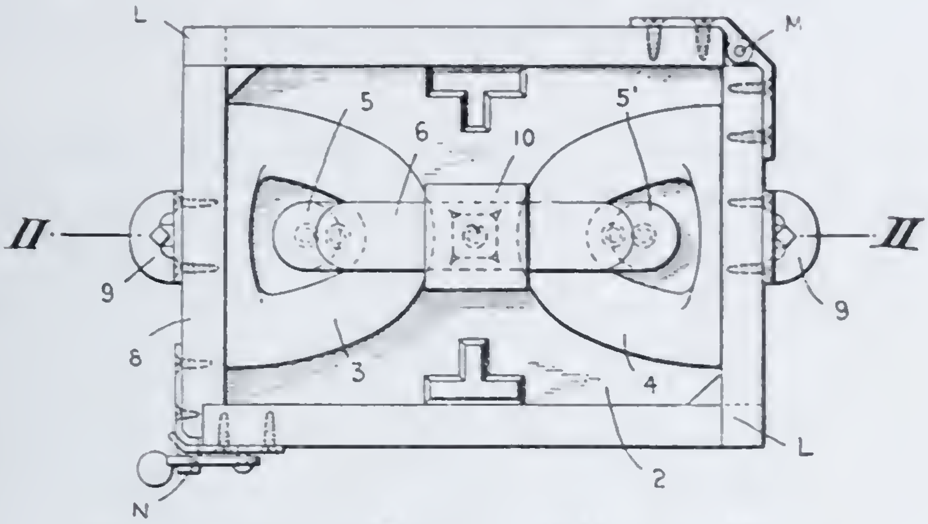

Fig. 11. Fourth Method of Making Molds.

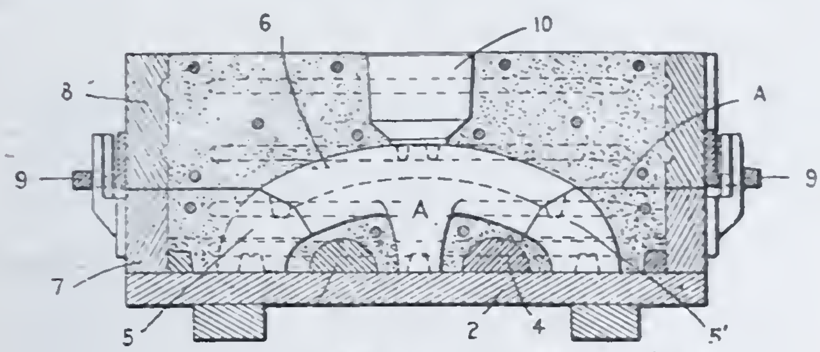

Fig. 12. Fourth Method of Making Molds.

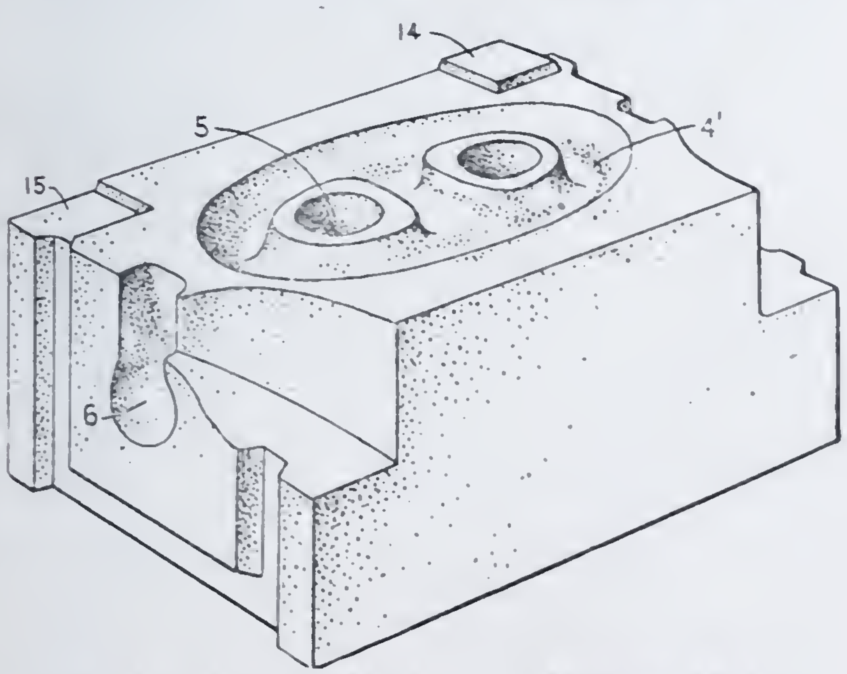

Fig. 13. Fourth Method of Making Molds.

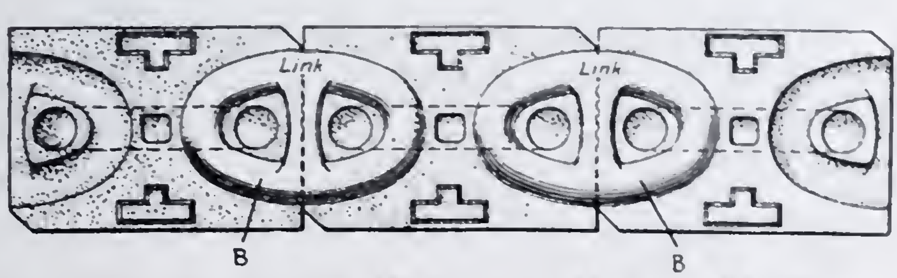

Fig. 14. Fourth Method of Making Molds.

The next step was connecting the links into chain. This was accomplished in two ways, both of which proved entirely satisfactory:

1. The continuous process, in which the entire chain was poured from one heat, into previously prepared and united molds, by filling one interlinked mold impression after another.

2. The pre-cast link process, in which half the links comprising a complete length of chain were cast separately, shaken out, cleaned, inspected and made ready for incorporation into finished chain. Subsequently, these links were placed into mold cavities and coupled up into continuous chain by pouring metal into other molds containing impressions for similar links interlinked with the pre-cast links.

This part of the foundry problem being satisfactory, the character of the mold was considered. Recognizing the vital importance of sound castings, it was determined that all links should be produced in dry sand molds. Naturally, the method of application of gates and risers also required study, but this will not be touched upon except to say that very excellent results were attained, both in pouring through the stud and through the side of the link.

Proper links being cast, they were subjected to heat treatment by placing them on a traveler and slowly passing them through a furnace in which the heat was automatically controlled by special contracting pyrometers. At the discharge end of the furnace, links were dropped into a quenching tank of water and thence slowly passed on a second traveler through a drawing furnace, and finally air cooled.

Before considering the testing of these links I will briefly outline the nature of ships' chain. Most specifications demand that it shall be made in 15-fathom shots, the number of shots being determined by the size of the chain. For instance, one-inch chain shall be 165 fathoms to a suit; and 3½-inch chain, 330 fathoms.

The main body of each shot is made up of common links known as "A" links; on either end an enlarged link designated as a "B" link, to which is attached on one end (under the rules of the American Bureau of Shipping) a long stud link known as a "C" link; and on the other end a link without a stud, known as an

"E" link. The shots are joined by a connecting shackle designated as "D." The use of the varied links at the ends of the shot is to permit the threading and joining of the shackle "D," and at the same time to permit the free working of this portion of the chain over the wildcat, thus avoiding the possibility of jamming in dropping the anchor and affording proper gripping of the shackling in hoisting the anchor.

Having the experimental links prepared for physical test, it was decided to subject them to the regular static tension test and also to dynamic strains. To accomplish these a vertical, screw-type, static testing machine of 1 000 000 pounds capacity and a standard Master Car Builders' drop testing machine with a 1640-pound tup (Fig. 15) were utilized.

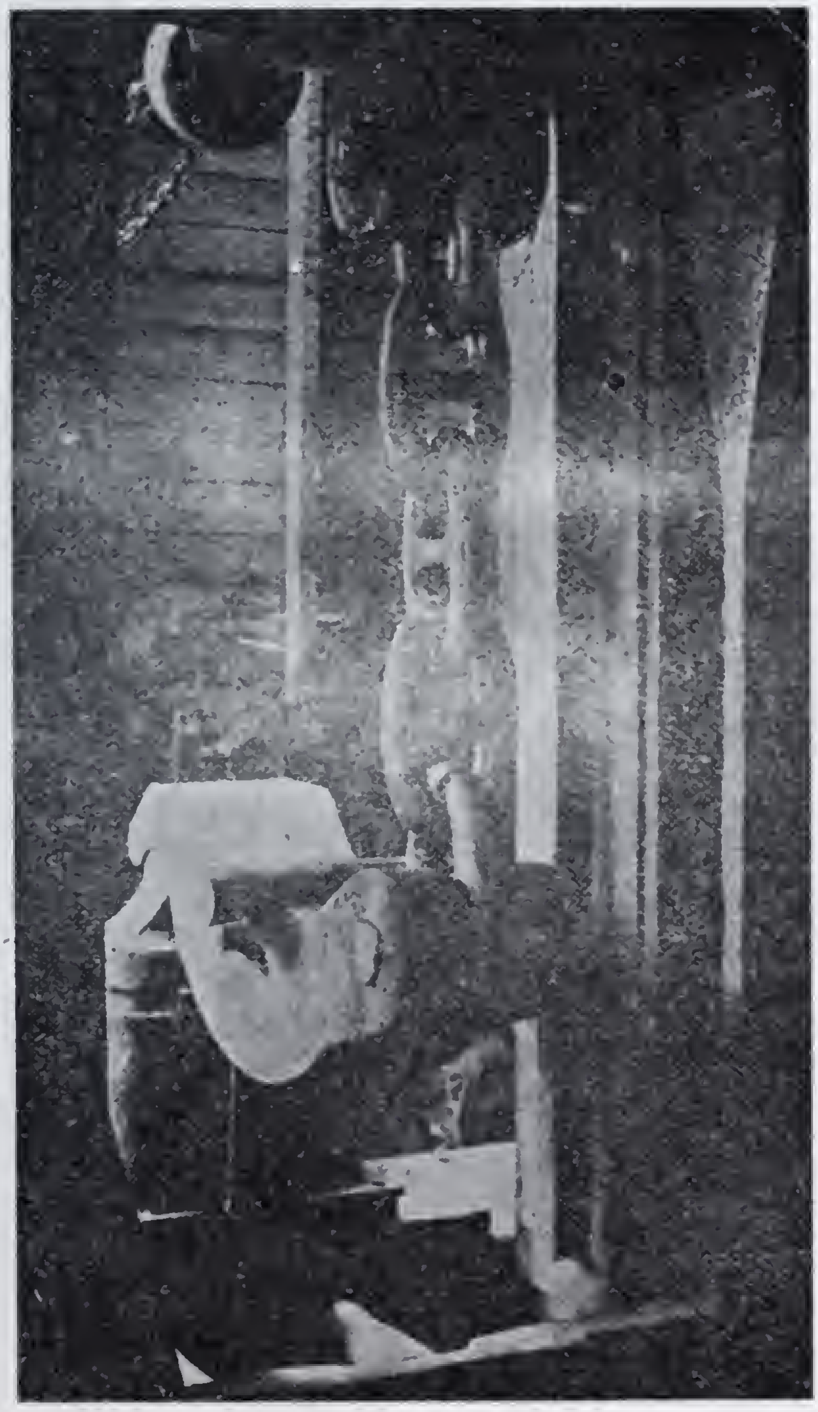

Fig. 15. Dynamic Tension (M. C. B. Drop) Testing Machine. Tup Raised.

Test chains consisting of five common stud or "A" links were subjected to a light static load—sufficient to reduce high bearing spots between adjacent links—which was then released and a measurement over the middle three links laid off. The elongation over this measurement was then taken at loads corresponding to the proof load, the breaking load, and the breaking load plus 40 per cent., as specified by the American Bureau of Shipping and Lloyd's Register of Shipping, for the corresponding sizes of wrought chain. After these loads had been applied, if no indications of fracture appeared, the chain was released and the elongation measured and a load to destruction was then applied.

With this assurance, test chains consisting of two sections of "A," "B," and "E" links coupled with shackle "D" were tested in the same manner, except that the elongation measurement was taken over the two "B" links. As subsequent tests were made along this line, no specific results will be given at this time.

Dynamic tests were then made on two-inch chain consisting of five stud or "A" links. These chains were installed in the testing machine by connecting the upper link in a shackle bar and the lower link in an equalizer shackle by means of a shackle pin passing through the eye of each link. This arrangement is clearly shown in Fig. 15, and is such that a part of the energy of the falling weight is transmitted to the test chain as a dynamic tensile test. The overall measurement of the middle three links of these test chains was laid off as in the static tests and the elongation measured after the third blow from each of the specified heights. The weight of the tup was allowed to rest upon the equalizer when readings were laid out and elongation measured.

These tests showing conclusively that it was practicable to manufacture ships' anchor chain by the casting method, representatives from the United States government, the Ship Classification Societies, the General Electric Company, and others interested were invited to be present at Sharon, Pa., at a series of tests to be made on February 28 to March 2, 1918. At this time 17 static tests were made with the results indicated in Table I.

TABLE I

STATIC TENSION TESTS OF "NACO" STEEL CHAIN

Test No.	Chain size in.	Weight of test chain, lbs.	Elongation in inches: After proof load	Elongation in inches: After breaking load	Elongation in inches: After Breaking load plus 40 per cent.	After Load at rupture lbs	Remarks
1	$1\frac{3}{8}$	40	0.03	0.04	0.08	213 600	Broke No. 3 link. Section of metal solid.
2	$1\frac{3}{8}$	40	0.03	0.04	0.07	198 700	Broke No. 3 link. Section of metal showed few small blow holes.
3	$1\frac{3}{8}$	40	0.02	0.04	0.09	180 700	Broke No. 3 links. Section of metal honeycombed.
4	2	123	0.03	0.06	0.13	456 400	Broke No. 4 link. Small shrinkage in each fracture.
5	2	122	0.03	0.06	0.09	400 000	Broke No. 3 link. Section showed solid.
6	2	122	0.03	0.05	0.10	403 000	Broke No. 4 link. Section showed solid.
7	2	225	0.20	0.27	0.45	381 900	Broke top "E" link. Section showed few small blow holes.
8	2	223	0.10	0.22	0.63	346 500	Broke bottom "E" link. Section showed few small blow holes.
9	2	223	0.07	0.14	Not obtained.	316 100	Broke bottom "E" link. Section showed few small blow holes.
10	$2\frac{1}{4}$	174	0.05	0.09	0.20	494 400	Broke No. 1 link. Section showed solid.
11	$2\frac{1}{4}$	174	0.07	0.13	0.33	495 400	Broke No. 3 link. Section showed solid.
12	$2\frac{1}{4}$	175	0.06	0.11	0.22	513 200	Broke No. 5 link. Section showed solid.
13	$2\frac{1}{4}$	172	0.02	0.05	0.14	502 400	Broke No. 3 link. Fractured through defect.
14	$2\frac{1}{4}$	171	0.03	0.07	0.16	491 900	Broke No. 5 link. No. 3 link defective.
15	2	...	0.65	0.65	0.67	452 700	Broke No. 2 link. Section showed solid. See also dynamic test No. 4
16	$2\frac{7}{8}$	251	0.00	0.00	0.00	764 700	Broke "E" link. Section showed few blow holes in one side.
17	2	...	0.72	0.73	0.74	467 400	Broke No. 3 link. Section showed small shrinkage one side. See also dynamic test No. 8.

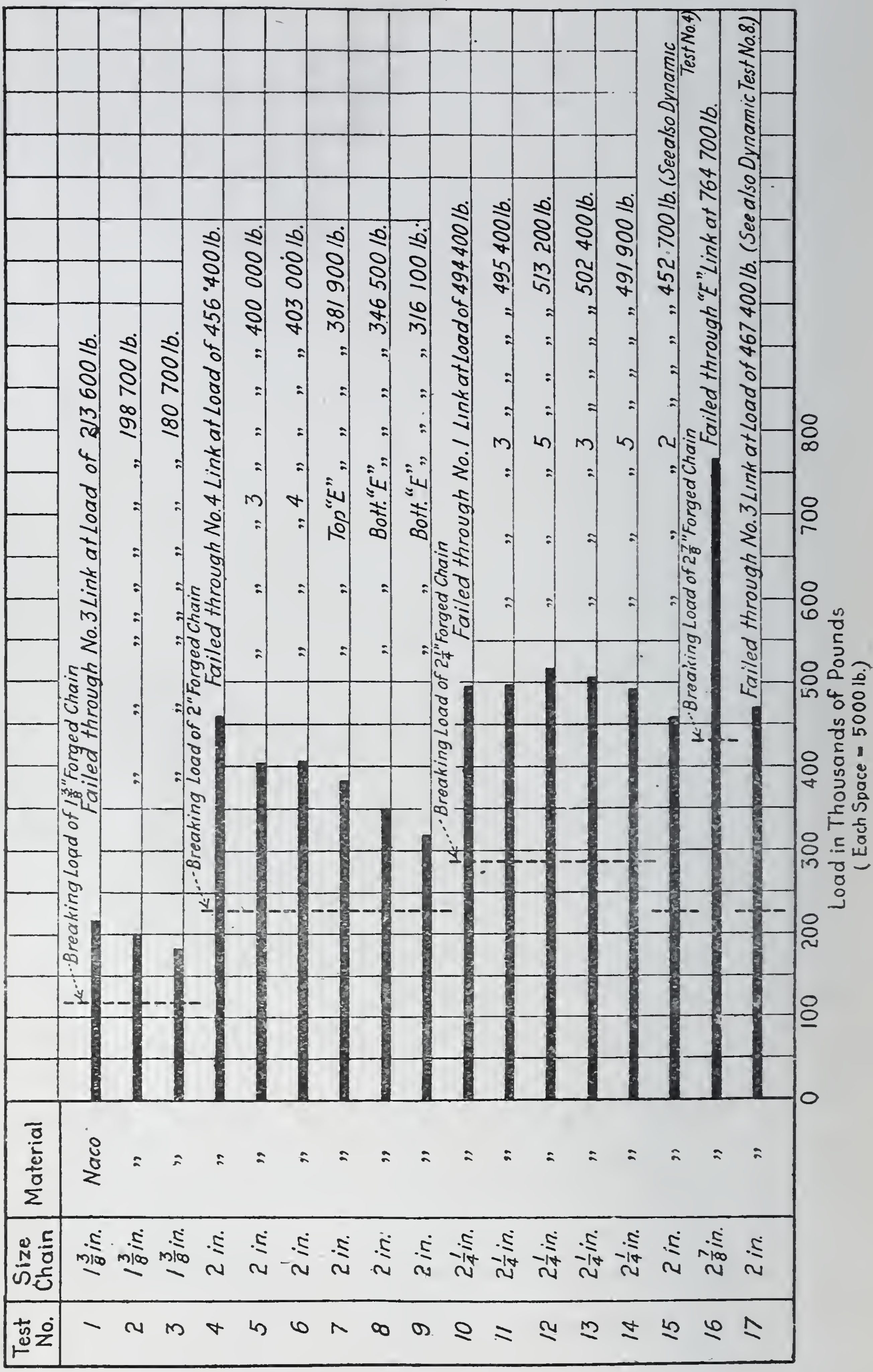

Fig. 16. Graphic Representation of Static Tension Tests (See Table I).

Fig. 16 indicates graphically the results expressed in Table I. Note also the breaking point of wrought-iron chain in comparison.

It is especially interesting to note the breakage of the links under these tests, as shown in Fig. 17–21.

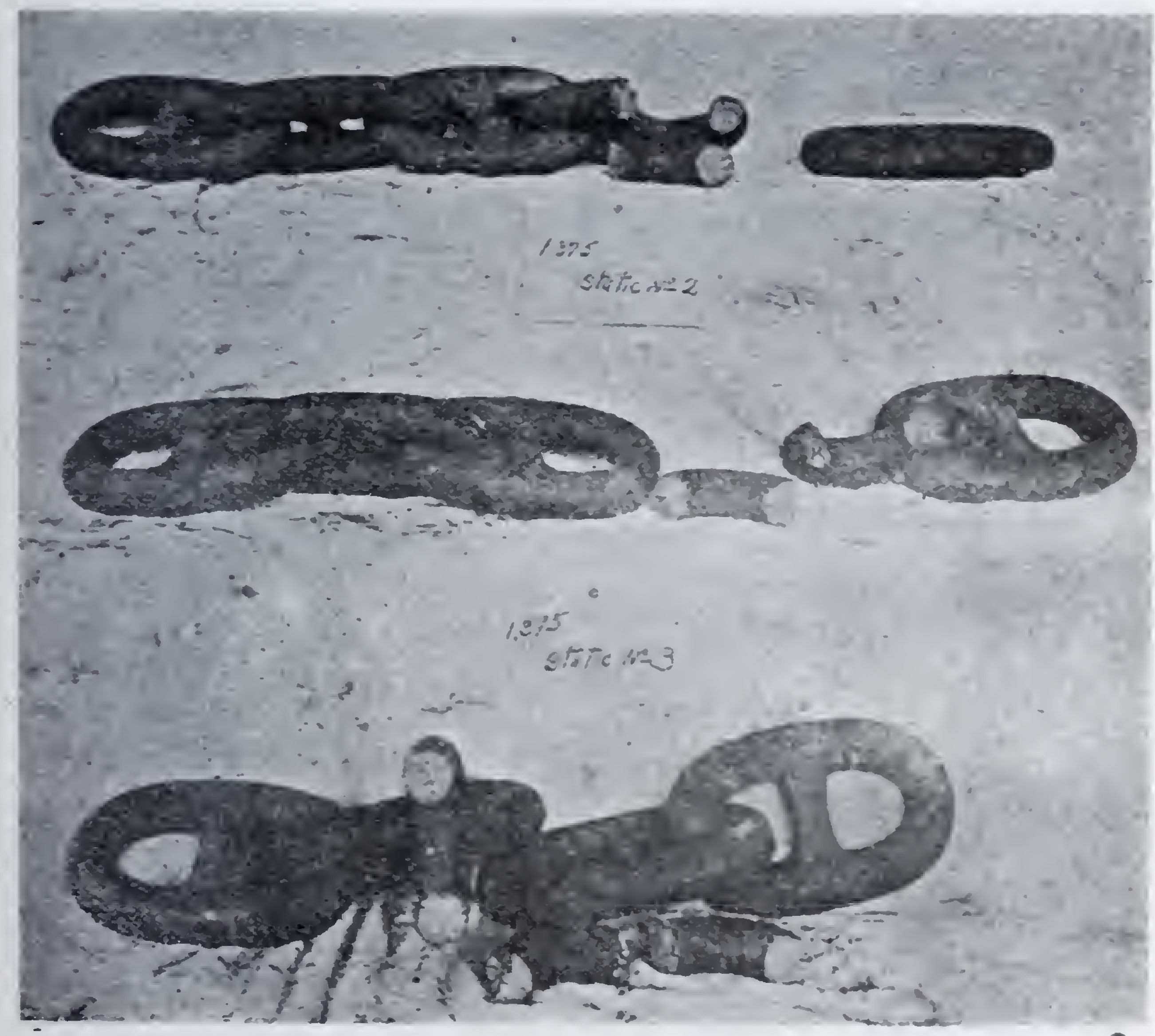

Fig. 17. Broken "Naco" Chain, Static Tests 1, 2 and 3.

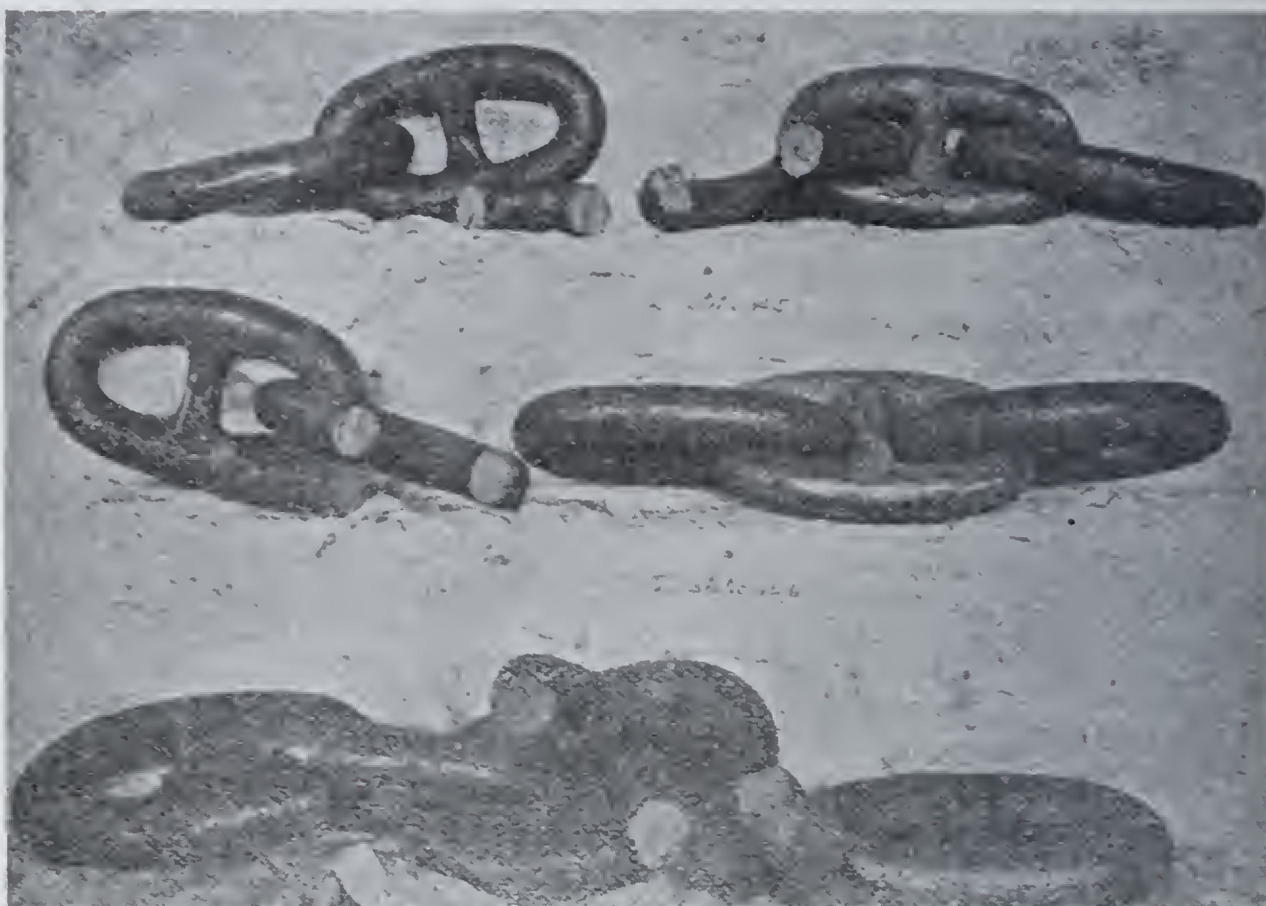

Fig. 18. Broken "Naco" Chain. Static Tests 4, 5 and 6.

Fig. 19. Broken "Naco" Chain. Static Tests 11, 12 and 14.

Fig. 20. Broken "Naco" Chain, Static Test 15.

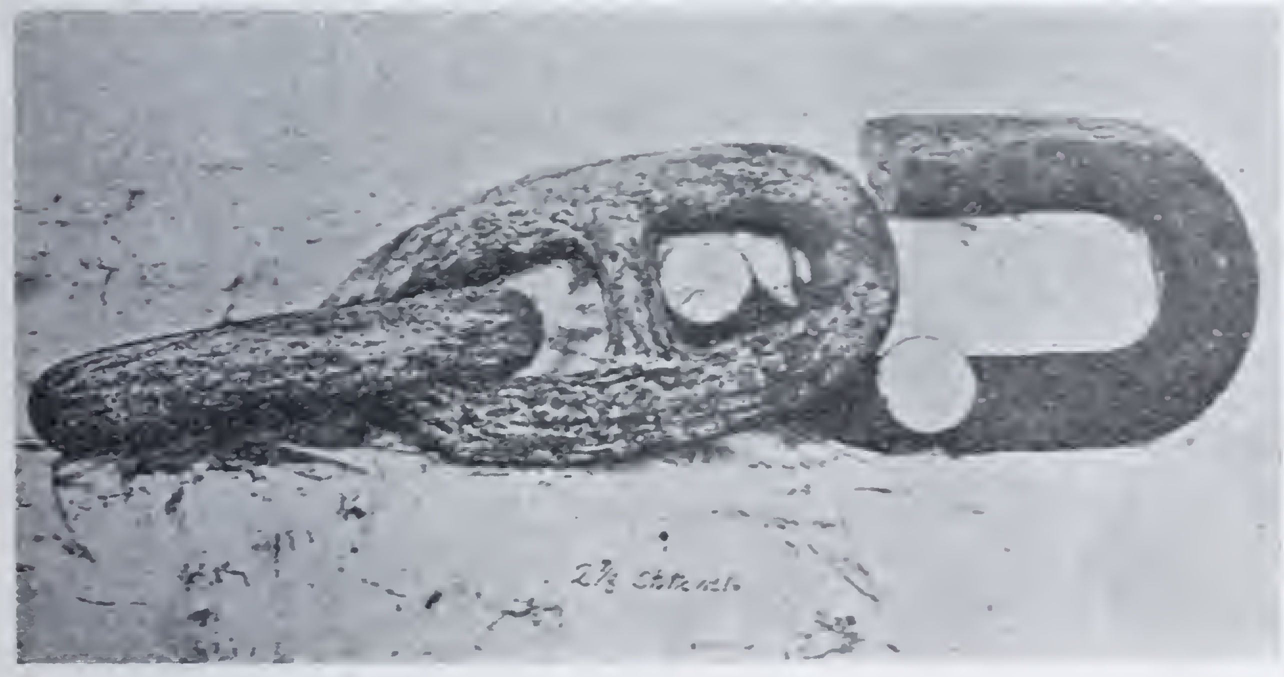

Fig. 21. Broken "Naco" Chain, Static Test 16.

As a further explanaton of test chains 13 and 14, it was found that these specimens had serious shrinkages on one side of the No. 3 link opposite the stud, and they were utilized to determine the influence of these defects. In test No. 13, the defective link broke through the defect at 502 400 pounds, and in test No. 14, the No. 5 link broke at 491 400 pounds, showing a solid section at the fracture. The second chain was re-tested and finally broke through the defect in No. 3 link at 502 200 pounds.

While neither of the foregoing could have been considered suitable for commercial purposes, and the defects were readily detected by a casual inspection, this specific defect is pointed out to show that the imperfection did not materially reduce the strength of the links.

To make the tensile tests and to secure a comparative evaluation necessitated reference to the requirements of the Ship Classification Societies. However, nothing of this character had been compiled as to the ability of ships' chain to absorb sudden shocks. In order that a comparative unit might be determined, three sample pieces of two-inch standard wrought-iron, stud-link chain, and two pieces of United States Navy stud-link chain were secured. The standard stud-link chain was fabricated by the hand-made method by a recognized manufacturer, and the United States Navy chains were samples from the Boston Navy Yard, manufactured by the third process mentioned above.

The results of these tests are shown in Table II.

TABLE II

DYNAMIC TENSION TESTS OF CHAIN

Test No.	Size, in.	Material.	Elongation, in., after 3 blows at 5 ft.	10 ft.	15 ft.	20 ft.	25 ft.	Total blows at 25 ft.	Total blows at 30 ft.	Total blows at 35 ft.	Chain broke on	Total elongation, in.	Remarks
1	2	Wrought	0.02	0.05	0.15	....	....	..	..	..	First at 20 ft.	0.15	Broke links 4 and 5.
2	2	Wrought	0.00	0.02	....	....	....	..	..	..	Second at 15 ft.	0.02	Broke No. 1 link.
3	2	Wrought	0.00	0.02	....	....	....	..	..	..	Second at 15 ft	0.02	Broke No. 1 link.
4	2	"Naco"...	0.01	0.05	0.09	0.13	0.27	50	20	..	None	0.65	Chain installed in static Machine. See static test No. 15.
5	2	U. S. Navy	0.10	0.34	0.68	1.37	2.21	6	..	..	Sixth at 25 ft	....	BrokeNo.1 link through weld.
6	2	U.S Navy	0.06	0.32	0.74	1.32	2.08	10	2	..	None	3.85	Surface fractures in all links. Chain installed in static machine and broke No. 2 link at about 241 000 lb.
7	2	"Naco"...	0.02	0.02	0.03	0.05	0.10	10	1	..	First at 30 ft.	0.24	Broke No. 4 link. Section shows solid.
8	2	"Naco"...	0.08	0.10	0.15	0.19	0.26	10	10	10	None	0.72	Chain installed in static machine. See static test No. 17.

The results expressed in Table II are indicated graphically in Fig. 22.

The special features of this test should be noted. They are as follows:

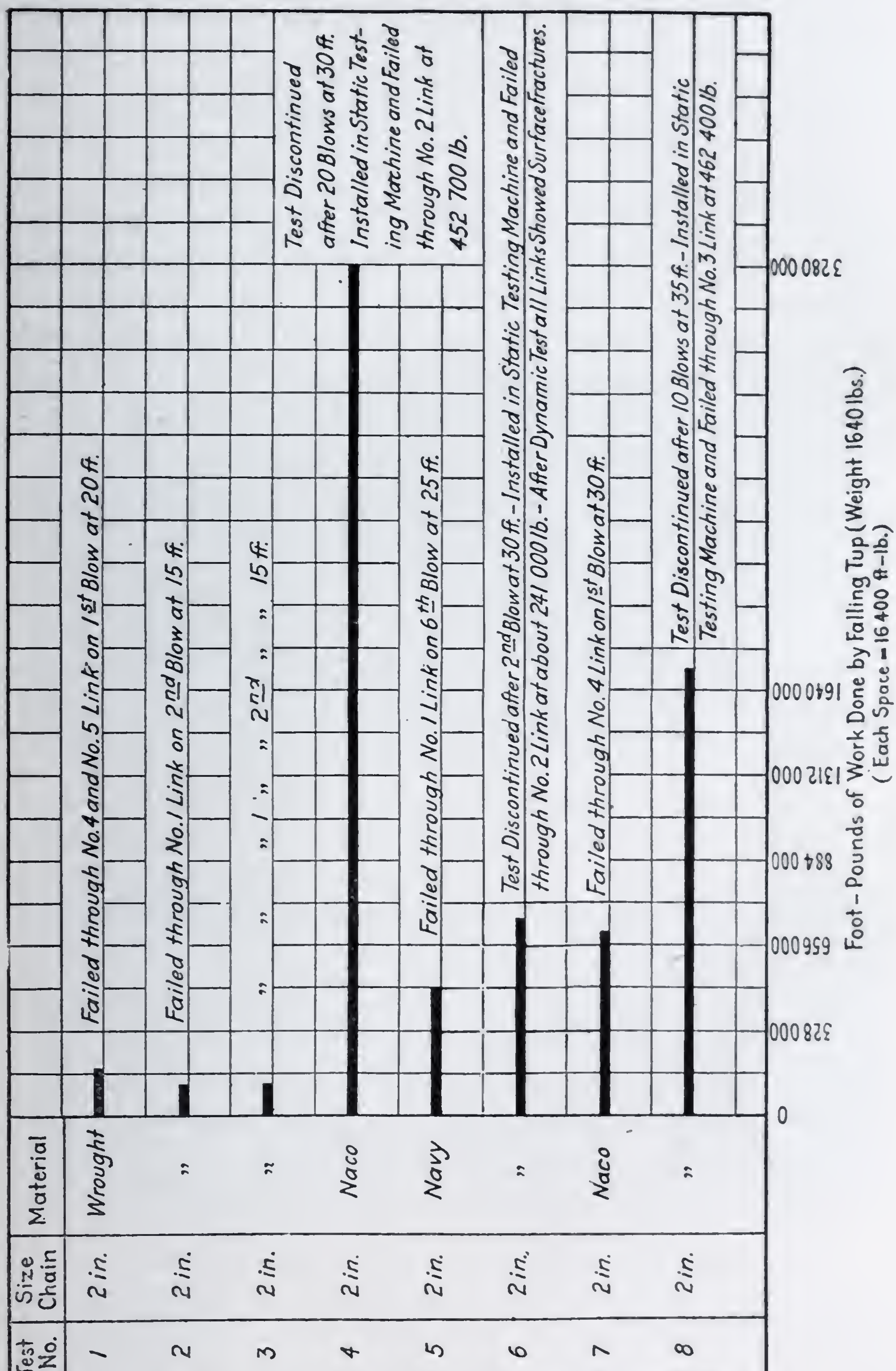

Fig. 22. Graphic Representation of Dynamic Tension Tests (See Table II).

Test No. 4: Two-inch "Naco" steel chain. This chain was subjected to:

3 blows at 5 feet.	3 blows at 20 feet.
3 blows at 10 feet.	50 blows at 25 feet.
3 blows at 15 feet.	20 blows at 30 feet.

This chain showed no signs of failure whatever after this severe treatment, and the elongation over the links measured 0.65 inch. This chain was then transferred from the drop machine to the static machine, and subjected successively to the proof load, the breaking load, and the breaking load plus 40 per cent.; after which the load was increased to 452 700 pounds, when the No. 2 link broke, showing solid sections at the fracture.

Test No. 8: Two-inch "Naco" steel chain. This chain was subjected to:

3 blows at 5 feet.	10 blows at 25 feet.
3 blows at 10 feet.	10 blows at 30 feet.
3 blows at 15 feet.	10 blows at 35 feet.
3 blows at 20 feet.	

The elongation over three links was 0.72 inch, with no signs of fracture; after which the chain was subjected to the same static load as in test No. 4, and broke through No. 3 link at 467 400 pounds, showing solid metal at the fracture, but with a small shrinkage at one side.

Test No. 6: Two-inch Navy chain. This chain was subjected to:

3 blows at 5 feet.	3 blows at 20 feet.
3 blows at 10 feet.	10 blows at 25 feet.
3 blows at 15 feet.	2 blows at 30 feet.

The test was discontinued at this point because of excessive elongation in the chain, which permitted the equalizer to interfere with its support and made it impossible to deliver the full blow to the chain. The elongation over three links was 3.85 inches, and each of the five links was slightly fractured in one or more places.

After the third blow at 20 feet the elongation over three links was 1.32 inches, and after the third blow at 25 feet it was 2.08 inches, and at this point the chain had distorted beyond the limit where it would work freely over a wildcat, thus becoming of no commercial value.

The results of the tests on the Navy specimens may be visualized by referring to the next two illustrations, Fig. 23, representing specimen No. 5, and Fig. 24, representing specimen No. 6.

Fig. 23. Broken Navy Chain, Dynamic Test 5.

Fig. 24. Broken Navy Chain, Dynamic Test 6.

As a result of these tests it was decided that tentative specifications should be prepared by Mr. H. Jasper Cox, of Lloyd's Register of Shipping, he agreeing to make this compilation.

On March 16, 1918, a special meeting of Committee A-1 of the American Society for Testing Materials was held in New York to consider the question of cast-steel anchor chain. At this meeting papers were read by Mr. W. L. Merrill, of the General Electric Company, and Mr. Chester K. Brooks, Research Engineer of the National Malleable Castings Company, on their research work in the development of the chain; also, a very instructive paper was read by Captain Henry M. Seeley, Superintendent, United States Steamboat Inspection Service, New York, on the use of the anchor chain, and difficulties experienced in actual service.

As a result of this meeting a subcommittee was appointed, which held its first meeting that day and decided that further tests should be made, particularly along the line of transvere shocks.

On April 5, 1918, transverse tests were made at the Sharon plant, at which time there were present representatives from the United States government; representatives of the American Society for Testing Materials; chain manufacturers; and a special representative from the War Industries Board—Mr. John C. Schmidt—who later was the Chief of the Chain Section of the War Industries Board.

The tests made at this time were to determine the transverse strength of the links under both static and dynamic loads. In the static test, individual two-inch common links were supported on two-inch diameter round pins spaced eight inches, center to center. A third round pin of two-inch diameter was placed transversely across the link at its center and the load applied through this third pin, with the following results:

Test No. 1
Wrought-iron link

Load, lbs.	Deflection, in.
25 000	0.00
50 000	0.01
75 000	0.06
100 000	0.33
125 000	0.83
145 000	1.66

Support pins slipped from under the link at 145 000 pounds load. Total number of degrees through which link bent was 53.5.

Test No. 2
"Naco" steel link

Load, lbs.	Deflection, in.
145 000	0.00
161 000	0.01
225 000	0.17

Fractured one side of link close to stud at load of 237 300 pounds. Test continued, and fractured remaining side at 145 000 pounds load. Section of metal through fracture showed solid.

In the dynamic transverse test, individual common links were supported in a standard Master Car Builders' knuckle-pin test block. The supports were ¾-inch radius and spaced 10 inches, center to center, the dynamic load being applied transversely at the center of the link through a plunger having a radius at its nose of ¾ inch. The results of these tests were as follows:

Test No.	Material	Fall of 1640-lb. tup, ft.	Deflection degrees	Remarks
9	Wrought-iron	6	21	No fracture.
10	Wrought-iron	7	32	No fracture.
11	Wrought-iron	8	. .	Link broke.
12	Wrought-iron	8	36	No fracture.
13	"Naco" steel	8	11	No fracture.
14	"Naco" steel	8	12	No fracture.
15	"Naco" steel	10	Not measured	Link broke on second blow at 10 feet.
16	"Naco" steel	12	Not measured	Link broke.

(*Note.* A link having a deflection greater than 12 degrees will not work in a wildcat.)

Reference has been made to the connecting shackles, "D"; for joining the shots of chain. Shackles made from "Naco" steel have stood the same severe punishment as the chain in experimental testing, and in all instances no failures were recorded, and this class of shackle will be utilized by the National Malleable Castings Company.

As a result of these tests both the American Bureau of Shipping and Lloyd's Register of Shipping approved the use of cast-steel anchor chain in merchant vessels, and issued testing requirements. These requirements are substantially complete save for the drop test on the various sizes. As all tests were conducted on two-inch chain, that size was taken as the standard until such time as data may be compiled in the actual manufacture of the chain. As a guide for inspectors the height of blows for intermediate sizes of chain may be obtained by interpolation.

It might be well to mention the fact that a heavier machine with a 3000-pound tup has already been constructed, and in the

near future drop tests will be made to determine the proper height and number of blows for each size of chain.

In May 1918 at a meeting of the Chain Section of the War Industries Board, Mr. E. C. Gillette, the representative of the United States Lighthouse Bureau, Department of Commerce, raised the question as to corrosion of cast-steel chain in salt water. Considerable discussion ensued and, at the suggestion of Mr. John C. Schmidt, the Chief of the Section, on May 20, 1918, the Lighthouse Bureau addressed a letter to the National Malleable Castings Company suggesting that a sample of chain be forwarded to the depot of the Third Lighthouse District at Tompkinsville, N. Y. On June 21, 1918, two sample pieces of this chain were received at this depot.

On August 8, 1918, this chain was placed on a buoy in Main Swash Channel, Lower Bay, New York harbor, but before going on station the samples were carefully examined as to diameter, special attention being paid to the caliber at the ends of links where wear would come in actual service.

On November 26, 1918, these samples of chain were examined and the writer made the following report to the Chain Section of the War Industries Board:

"November 26, 1918.

Subject: Cast-Steel Chain and Wrought-Iron Chain.

Samples: One piece containing Cast Steel

Designated *No. 1.* 1—1½" Open Link
1—1 7/16" Stud Link
1—1⅜" Stud Link

Total Weight—26 lbs. 12 ozs.

One piece containing

Designated *No. 2.* 5—1⅜" Cast-Steel Stud Links

Total Weight—39 lbs. 5 ozs.

These two samples coupled with

Designated *No. 3.* 3—Links of 1⅝" Open Link Wrought-Iron Buoy Chain.

And all attached to 1⅝" Buoy Anchor Chain, and forming a total length of 90' 0".

The foregoing attached on a

Tall Can Buoy—2nd Class.
Weight of Buoy—5990 lbs.
Depth of Water—22 feet.

Buoy was placed on station at Station S-3 in the 3rd Lighthouse District on August 8, 1918, and known as East Knolls Buoy, Main Swash Channel, Lower Bay, New York harbor.

Examination: November 22, 1918.
Witnesses: E. C. Gillette, Lighthouse Bureau.
J. T. Yates, Lighthouse Bureau.
Geo. F. Wilhelm, National Malleable Castings Co.
A. E. Crockett, Asst. Chief, Chain Section, War Industries Board.

Buoy was lifted but anchor not raised.
Inspection showed the following:

ABRASION

Result:

Sample No. 1.

1⅜″ Stud Link attached to Buoy Shackle Swivel. Abrasion at bottom of link—1/32 inch.

1 7/16″ Stud Link—1/32-inch abrasion on bottom of link joining 1⅜″. No abrasion on the other bottom contact.

1½″ Open Link—no abrasion.

Sample No 2.

5 Links 1⅜″ showed a uniform abrasion of 1/32 inch scant on the bottom contact of all links.

Sample No. 3.

Showed a uniform abrasion of 1/32 inch scant on the bottom contact of all links.

CORROSION

All Links of *Cast-Steel Chain* showed an oxide deposit too light to be determined by measuring instruments on hand.

Links were wash cleaned and measurement showed as originally immersed.

All Wrought-Iron Links had corroded to the extent that the laminated formation of the material was indicated, but there was no appreciable change in size of the material.

Buoy was replaced with chain as originally attached and will be lifted in one year approximately from date of original installation, namely, August 8, 1919, and Mr. E. C. Gillette, Lighthouse Department, will make report to the various Governmental Departments represented in the Chain Section.

A. E. Crockett,
Asst. Chief, Chain Section."

DISCUSSION

MR GEORGE H. DANFORTH*: I think we are particularly fortunate in having Mr. Crockett give us this paper to-night. It is merely a forerunner of the beneficial results that will come out of this war. There have been times when we as a nation have been pretty severely put to it for ways and means. Mr. Crockett has shown the situation as regards one detail and I thoroughly believe that in the not far distant future we shall be able to present other developments of a similar character. The overcoming of the difficulties and the imperfections of hand processes by what is practically a machine process is one of the things that I think we should particularly note in the use of this cast-steel chain. It replaces a hand-made product entirely.

MR. J. R. MASON†: In the experiments which you made in testing the breaking strength of cast-steel chain, was any attention given to the reduction in area?

MR. A. E. CROCKETT: Not in the transverse blows in the tensile tests made. At least, very little attention was paid to this. We gave attention rather to the condition of the fracture than to any reduction in area. Our main thought was to note whether the material was spongy; whether there were any shrinkages; whether there were any blow-holes, or any conditions that might prove dangerous. Salt water getting into the blow-holes, for instance, would soon cause disintegration.

MR. J. F. CRAVEN:‡ I think with Mr. Danforth that we are to be congratulated on having Mr. Crockett with us to-night on a subject with which he is so familiar. I would like to ask him a few questions. I noticed in one of the tables that the larger links showed greater tensile strength than their propor-

*Structural Engineer, Jones & Laughlin Steel Co., Pittsburgh.

†District Sales Manager, Wickes Boiler Co., Pittsburgh.

‡Craven Research Laboratories, Pittsburgh.

tional increase in size would indicate. Is that due to any peculiarity of the construction of the links? I would also like to know what are the limitations in the size of cast-steel chain, as I note in the tests for corrosion the buoy chain was from 1⅜ inches up. Has the limit been determined for the smaller sizes of steel chain?

Mr. A. E. Crockett: In regard to the smallest size, it is generally considered best, as far as our experience has gone, to limit it to 1⅜ inches as the low level. The reason is more because of the casting problem than from the nature of the material itself. The upper range seems to be without limit. As to the nature of the tests that were made on the light sizes and the proportion of breaks in the light sizes as compared with the 2¼- and 2⅞-inch, some of that was due to the construction of the stud that I spoke about, where it came to the side of the link which had to be changed by adding a small fillet.

Mr. J. F. Craven: I would like to know more about the proportion of elongation in the several sizes if that information is available.

Mr. A. E. Crockett: In the two-inch size we had 0.65 inch where 20 blows had been struck at 30 inches, and we had 0.72 inch where 10 blows had been struck at 30 inches and 10 at 35 inches; so there is little appreciable difference in the cast-steel links themselves. We varied our blows and mixed them up.

Mr. Frank L. Egan:* I should like to ask Mr. Crockett about the pouring of these links. Am I correct in understanding that the gating of the links is invariably made from the side of the link at the stud?

Mr. A. E. Crockett: No, some have been through the center of the stud and some through the side of the link.

Mr. Frank L. Egan: As far as the tests have gone, which method would seem to be superior?

*Engineer on River Equipment, Carnegie Steel Co., Pittsburgh.

MR. A. E. CROCKETT: I am not a foundryman, but from the talk I heard among the foundrymen some were contending for one method and some for the other. Mr. Cox in his paper states that he believes it advisable to pour through the center of the stud because the stud is least likely to be affected by any defect that might occur.

MR. FRANK L. EGAN: Then the principal reason for gating through the stud, is that any porosity due to the gate would be in the stud which is always in compression?

MR. A. E. CROCKETT: That seems to be the general impression.

MR. FRANK L. EGAN: Has anything definite been determined regarding the size of sink head? Do you carry extreme heads, and what percentage of the link weight is sink head in the chains as now made?

MR. A. E. CROCKETT: These matters did not come under my observation.

MR. FRANK L. EGAN: Do the links when bent to a 12-degree angle give any trouble in going through the wildcats? In running cast-steel chain is there any difference noticed in the way the chain enters and leaves the tubs, and does it handle as well over the wildcats as the standard forged link chain?

MR. A. E. CROCKETT: Twelve degrees is the danger point of free action in the wildcats. Each link being of exact dimensions, it should handle better than wrought chain.

MR. FRANK L. EGAN: What method is used to cut the fins caused by the flask parting, and to finish the chain ready for service?

MR. A. E. CROCKETT: Grinding and chipping.

MR. J. F. CRAVEN: One matter that was not touched upon is the matter of cost. I would like to know, if Mr. Crockett can tell, about how the cast-steel compares with the wrought-iron chain?

Mr. A. E. Crockett: I can not answer that from the foundry standpoint. I can answer only that, from what I would judge from bids that were opened, it was practically the same as the wrought-iron.

Mr. J. H. Minton, *Chairman*:* I would judge that there may be considerable labor saving in the manufacture of this chain and the thought occurs that it may be cheaper after it is developed into more of a commercial proposition.

Mr. A. E. Crockett: I could not answer that question because I am treating this purely from the development standpoint. We were imbued with only one thought when this first came out, realizing that there was a shortage of ship cables. When I went down to Washington on April 23 to assist the Board, and looked over the field and saw the terrific demand we were facing, our only thought was to get the chain, and we, of course, left it up to the Emergency Fleet to take care of the purchasing end. We took care of endeavoring to find the chain.

Mr. George H. Danforth: I would like to ask Mr. Crockett if he thinks there is much possibility of developing this chain in the smaller sizes, down to one inch or three-quarter-inch?

Mr. A. E. Crockett: I can not answer that. I have not seen anything yet that would justify me in believing it. There are other processes that are developed which I believe will answer the question of making chain in the lighter sizes, getting away from the old hand-made method and from the great personal equation that enters into chain making because, as it is made to-day and as it has been made, I do not know of anything that typifies a personality more than a chain.

Such, gentlemen, has been the development of this product, which has been solely from the great needs of your Government in the dark days that have passed, let us hope, forever.

*Assistant Engineer, Pennsylvania Lines, Pittsburgh.

Before closing, I desire to pay tribute to the men who have labored so hard and faithfully, without a thought of gain, to answer their country's call. I desire, also, to acknowledge the assistance given me by Mr. Chester K. Brooks of the National Malleable Castings Company, Mr. W. L. Merrill of the General Electric Company, and Mr. H. Jasper Cox, of Lloyd's Register of Shipping, whose collected data have been freely drawn upon for this paper. The slides used with the paper were furnished by Mr. Brooks.

THE DESIGN OF HEATING FURNACES FROM A PRACTICAL STANDPOINT

By George J. Hagan*

In order that you will not expect a highly technical treatise on furnace design, I want to preface my remarks with the statement that I am not a technical man. My entire experience in the design and construction of industrial furnaces has been gained from practice, and what little success I have met with has resulted from combining this practice with ordinary common horse-sense. Therefore, if this paper savors of being written with a trowel instead of a pen, you will understand the reason, and no further apology on my part will be necessary.

I have selected as a subject the design of heating furnaces from a practical standpoint and propose to deal with heating furnaces in general for various weights of stock from light to heavy, and the design and method of construction of such furnaces. Another subject that has been given considerable attention lately is that of continuous furnaces for wash heat. I will give you my views on this subject for what they are worth.

Having spent a considerable part of my time in the sheet and tin-plate industry, I will first deal with furnaces in that field. I went into this business a great many years ago in the construction end for one of the principal furnace engineers of this country. In those days the furnace most generally used was known as the Welsh furnace. Compared with present-day construction, these furnaces were nothing but mere shells. The principal feature about them was the hollow hearth through which the gases passed in various directions on their way to the stack. Quite a little ingenuity was displayed at times in the designs of these passages or flues with a view to keeping the gases in contact with the under side of the hearth as long as possible. The theory was to extract as much as possible of the heat from the gases before they

*General Manager, Geo. J. Hagan Co., Pittsburgh.

reached the stack, thereby effecting a great saving in fuel. It was also claimed for these furnaces that the bars and packs were heated more readily and a better condition generally obtained.

While I have a wholesome regard for theory, I have found on many occasions that theory and practice do not harmonize, and that the best results have often been obtained by following the course directly opposite to that which was theoretically correct. The Welsh furnace is an example. The general construction of these furnaces was flimsy, the walls being built with a nine-inch refractory lining backed by 4½ inches of red brick. The crown was nine inches and built straight. The hearth formed a covering for the flues already mentioned and was only 2½ to 3 inches thick. When the furnace was first lighted up, the bottom did heat very readily until the working temperature was reached, after which the heat traveled through the bottom into the flues, where it was carried off by the stack gases. In other words, the expensive and complicated hollow hearth construction merely acted as a superheater for the stack gases. The difficulty of keeping this hearth in proper condition will be apparent. Temperatures, as a rule, ran about 500 degrees higher than actually required.

I always questioned the theory of the hollow-bottomed furnace being a fuel saver for this class of work, and a benefit in other ways, but it was the custom to use this class of furnace, and customs are pretty hard to shake. Chance, however, gave me the opportunity I was looking for to prove my argument. The bottom in one of these furnaces had collapsed and we were called upon to make a quick repair job. All the old brickbats around the place were gathered up and thrown into the openings, making the bottom perfectly solid and cutting the draft passages off from the stack. A temporary stack connection was made and operations resumed in record time. After the bottom had obtained a good soaking heat this furnace was found to operate far better than the others. This killed one theory; it yet remained to determine the relative efficiency from a fuel-consuming standpoint. Inasmuch as the furnaces were gas fired, this was easily accomplished. Meters, properly tested, were applied to each furnace and the results showed a consistent saving of 12 per cent. in favor of the solid bottom. These experiments led to the building of a

far more substantial furnace in which the efficiency was considerably increased while the maintenance was very much reduced.

There is a very much greater demand to-day for sheet and tin mill tonnage than there was in the time of the old Welsh furnace; the automobile being one of the causes of this increase and, incidentally, of the improvement in the art.

An attempt to meet the demand with the old-style furnace was made by running up the working temperatures much higher than the material required. This resulted in a rash, hard flame unsuitable for proper heating. Little attention was paid to quality; anything passed as long as tonnage was turned out, and even wasters that could be utilized as cut-downs were not considered serious objections. Manufacturers, however, soon began to realize the enormous losses they were suffering from improper heating and this, coupled with the continued demand for better sheets, compelled changes in the designs to meet the new conditions.

Hearth areas were increased, the furnaces generally made larger, and the walls thickened up. Double instead of single furnaces were adopted, with partition walls permitting of both sides of the furnace being used at the same time. With this construction, one side of the furnace can, without any detrimental effect, contain a hot charge while the other side is ready to receive a cold one. Furnace temperatures were cut down so as to maintain the proper heat for working the materials. This was accomplished by charging larger tonnage and allowing a greater time for the materials to absorb the requisite amount of heat, while at the same time the temperature of the off-going gases was reduced, effecting further economy. Considerable attention was given to the question of excess air for combustion, with the result of practically eliminating the serious troubles and losses due to scaling. In fact, to-day, black tin-plates of 32 gage for tinning purposes, high-grade sheet that will stand spinning, and deep drawn work—such as "tea-tray stock"—can be heated with scarcely a trace of scale forming. These latter stocks require surface finish as nearly perfect as possible, and to secure this the heating had to be absolutely uniform and the scale eliminated. Oil as fuel for this purpose was not found satisfactory on account of the pitting that

occurred on the surface of the sheets. Natural gas was ideal, but the scarcity of it, coupled with the uncertainty of the supply and the high cost as compared to coal properly fired, gradually resulted in coal being adopted as the logical fuel; so that to-day I am safe in saying that I have equipped 85 per cent. of all the sheet and tin mills of this country with automatic stokers for coal burning.

The combination sheet and pair furnace has given excellent results. This type consists of two furnaces in tandem, with a combustion chamber or fire-box at one end. Next to the fire-box is the pair-heating furnace, then the sheet or final heating furnace. To-day, in our best working furnaces, the crown runs in a straight line from the stern wall to the front line of the bridge wall, thence it slopes downward. This slope, as a rule, is 1¼ inches to the foot. The height of the skew-back line at the front wall of the furnace must be 3 inches greater than the maximum width of the sheet which it is possible to work on the particular mill to which the furnace belongs. The modern furnace is known as a double furnace. For instance, in a furnace designed for a given sized mill, the width of the door to each chamber is 6 inches wider than the maximum width of the sheet. Each chamber of the sheet-heating furnace must have sufficient room to permit of edging the sheets. The chambers are charged with a pack of iron on the hearth in line with the doors and, as a rule, a space of 13½ to 18 inches is allowed on each side of the pack for edging. The combustion chamber is designed to suit the fuel being used, coal being the most common fuel in practice to-day. In designing this furnace for coal, if hand firing is employed, the grate area should not be less than 20 per cent. of the hearth area. If it is stoker fired, naturally the chamber must be designed to suit the stoker that is applicable for the purpose.

Before leaving the question of hollow-hearth furnaces, there is an exception I want to make in favor of this type, and that is in regard to the malleable-iron annealing furnace, which is more efficient with a hollow bottom. This is easily explained. The tonnage charged into these furnaces is of considerable volume. The pots in which these materials are packed are charged directly on the hearth of the furnaces and annealing requires several days. It is found when starting up the fires on a charge of malleable

iron for annealing that the hollow bottom will give off heat from the flues until the temperature of the hearth and temperature of the bottom chamber have become equalized. The maximum temperature of the working chamber I have found to be about 200 degrees F. higher than that of the flue-gas. Thus there is a period in the operation of the malleable annealing furnace in which the heat travels the reverse way, but this period is of short duration, as the fires are then damped down and the materials are allowed to soak under their initial heat.

The constant demand for improvement in the sheet and tin mill industry called for radical changes in pair-furnace design. It is through this furnace that the bars first travel in the rolling process. For high-grade work the bars are pickled and if an oxidizing flame were carried in the furnace the beneficial results of the pickling would be done away with. A furnace that has met the requirements admirably and has been used quite extensively by a number of manufacturers is the Allis patented continuous pair-heating furnace, shown in Fig. 1–3.

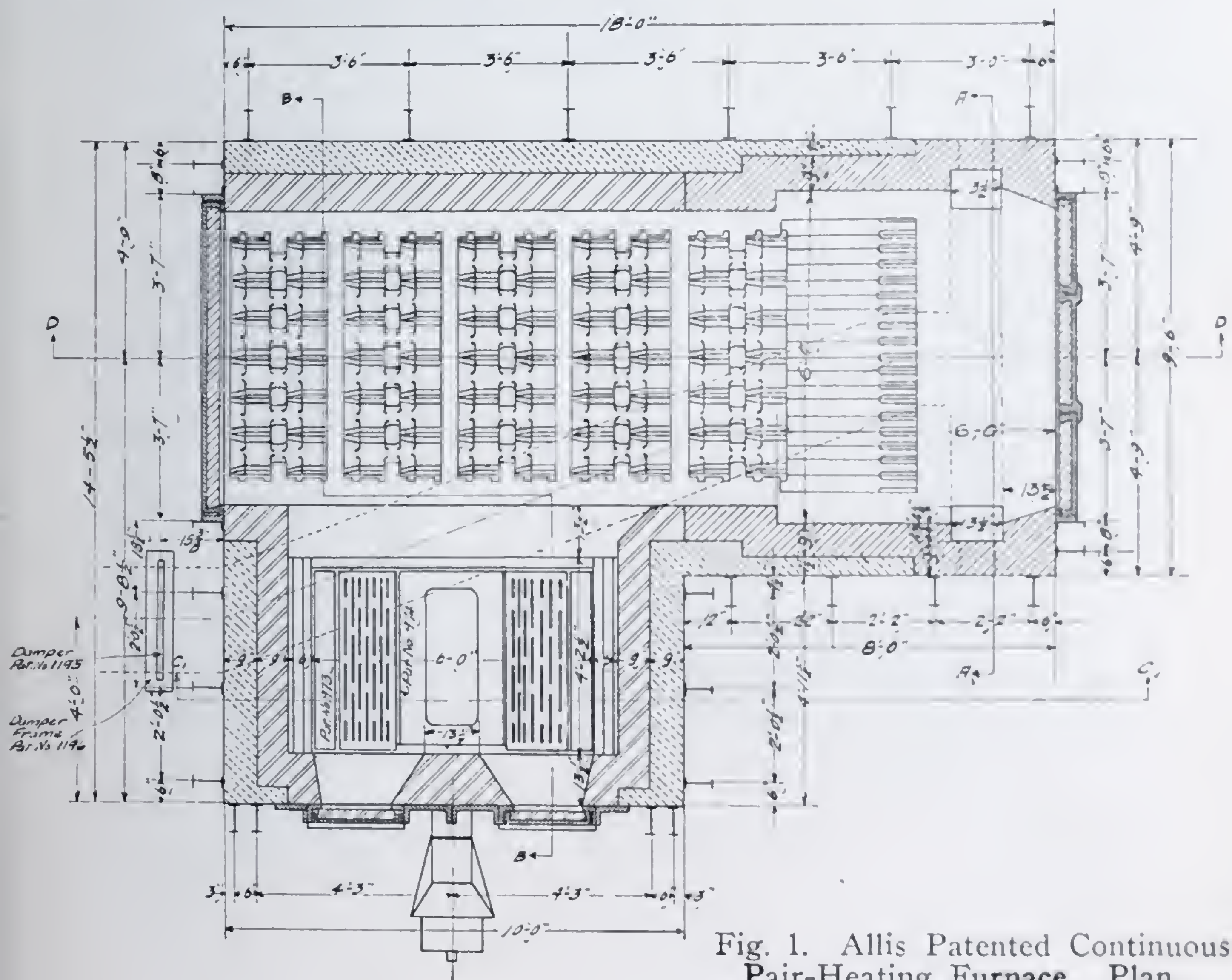

Fig. 1. Allis Patented Continuous Pair-Heating Furnace. Plan.

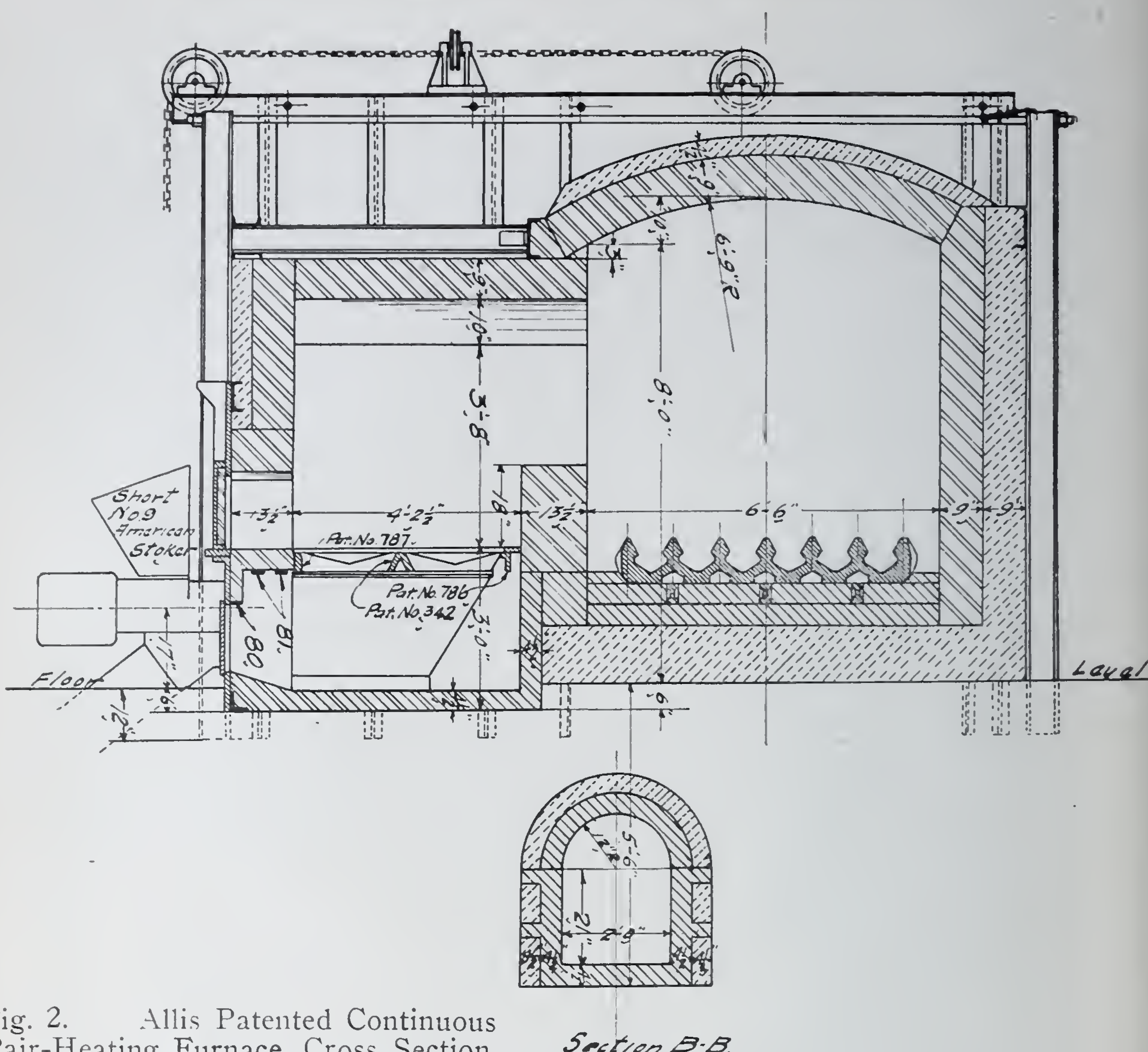

Fig. 2. Allis Patented Continuous Pair-Heating Furnace. Cross Section.

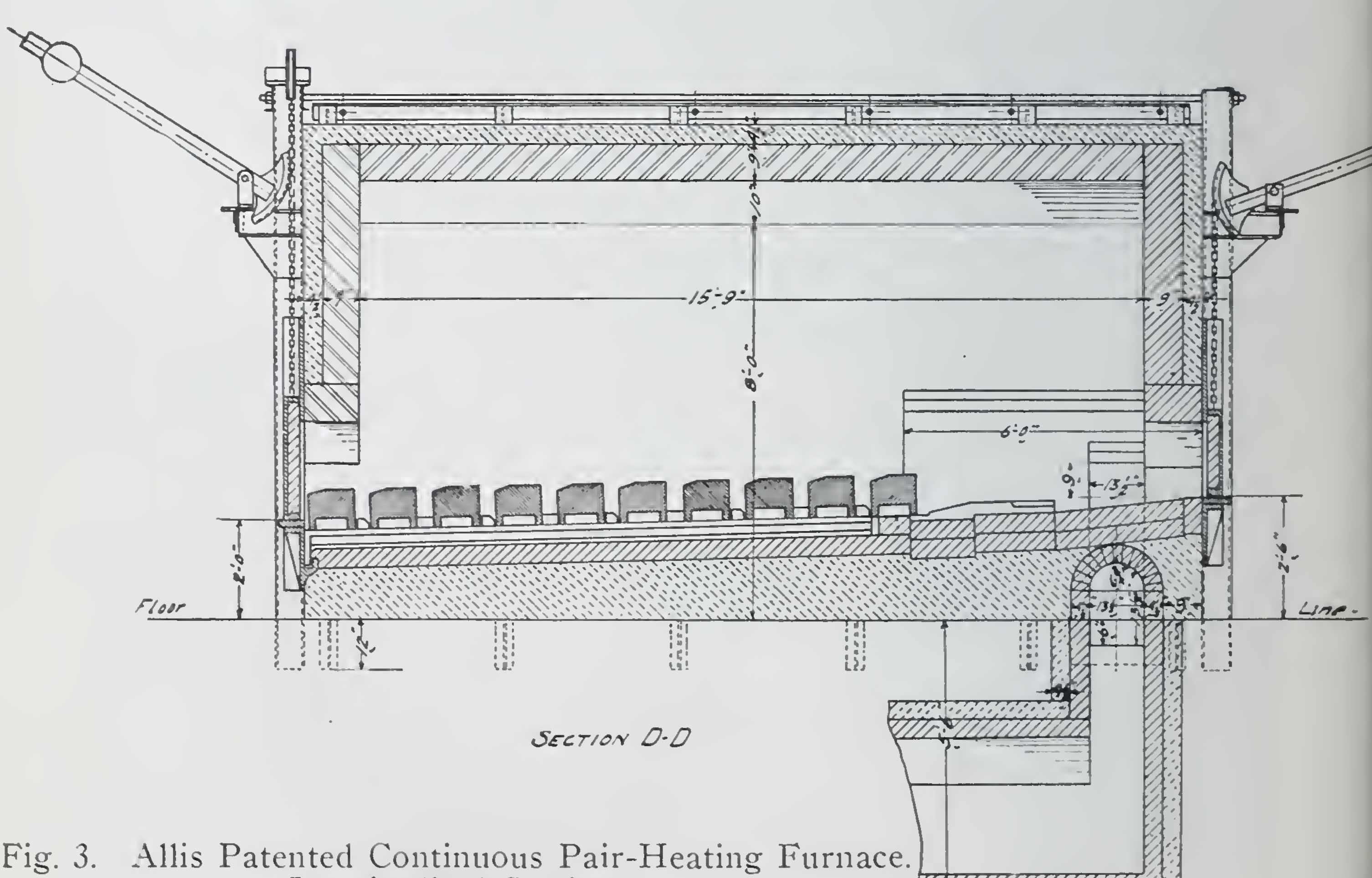

Fig. 3. Allis Patented Continuous Pair-Heating Furnace. Longitudinal Section.

So far there has been no mention made of annealing light stock. Light sheets are stacked close and box annealed; that is, the sheets all come in contact and are piled one upon another on a cast-iron bottom to a height to suit the annealing equipment—often four to five feet. These sheets being light are, of course, all handled by hand. In sheet-mill practice the charge runs anywhere from 15 to 25 tons. A cast-steel box is put over the pile of sheets and allowed to rest on the same bottom on which the sheets bear. Sand is used to seal the box at the bottom, and the complete charge with the box and bottom is rolled into the furnace by mechanical means. The type of furnace for annealing this grade of stock formerly used a hollow bottom, practically the same as above mentioned. These furnaces were only about 7 feet wide and 14 to 15 feet in depth. Natural gas, producer gas, oil and coal were the fuels used, the coal being hand fired. The first boxes and bottoms for containing the sheets were of heavy plate riveted construction, but in recent years a demand for longer and wider sheets was made. This demand, naturally, could not be taken care of without changes in the furnace equipment, and to-day the modern furnace employs very heavy cast-steel bottoms and boxes, naturally adding weight and area, while the charge is somewhat heavier on certain orders and the demand for quality is becoming more insistent right along. In annealing the sheets, the temperatures should be absolutely uniform all around the box. The standard furnace is a stoker-fired furnace of continuous bridge-wall construction, with draft outlets at the low point on the far side of furnace from the bridge-wall. The bottoms and annealing boxes are kept at a certain distance from the hearth so that the flames or gases can pass between the hearth of the furnace and the under side of the boxes. You will note that the height of the crown at the bridge-wall side of the furnace is much higher than the crown at the same relative point on the far side of the box. This was essential in order that the hot gases coming over the bridge-wall should have greater room for expansion and thus prevent severe action of the flame on the top of the annealing boxes. The gases pass over the top of the box and down along the sides. A slight excess pressure is carried at practically all times, thus allowing the furnace to fill completely with flame.

The bridge-wall construction permits of increasing or decreasing the height; thus, when a furnace is first put in operation and an adjustment is required for more uniform distribution of heat, it is an easy matter to take care of this. This furnace has proven a very marked improvement over former practice where the hollow bottom and other fuels were used. It formerly required 14 to 18 hours to bring a 20-ton charge up to correct annealing temperature, while this particular type of furnace will bring a 25- to 30-ton charge up to annealing temperature from a cold furnace in 10 to 11 hours of actual firing. After the correct temperature has been reached—approximately 1500 degrees F.—these boxes are allowed to soak. The soaking period varies somewhat in different plants, but the correct practice is to allow the boxes with their charge to soak from 10 to 15 hours, by which time the sheets and boxes have practically cooled down to a point where the box can be pulled and removed immediately. Of course, to follow out these ideal conditions correctly, a large number of furnaces is required to take care of the tonnage, but there are really very few plants which are equipped in this way. Common practice is to bring the charge up to annealing temperature, allow it to soak for five or six hours, and then remove; but allow the box to remain until the charge has cooled down to a temperature at which the box can be removed without danger of scaling the sheets by exposure to cold air. This latter course is very severe on the boxes and if the charge is allowed to cool down too rapidly the annealing is not as good.

In jobbing- and plate-mill practice the greater part of the stock is open annealed. This really should not be classed with annealing when compared with the interpretation "annealing sheet-mill stock." Open annealing is nothing more than the reheating of plates, which does, to a large extent, remove the stresses in the plate after it has cooled down from its initial heat. These plates, as a rule, are kept on conveyors or casters after they leave the rolls; and are charged almost immediately into an open annealing furnace, the term "open annealing" implying that the plate is exposed to the direct flame. These plates are charged from the casters to the annealing furnace by hand, which calls for skillful manipulation of the tongs. The old practice, which is still

extensively followed, uses a solid-bottom furnace of continuous bridge-wall construction. These furnaces are 8 to 10 feet in width and vary in length, usually being a little over twice as long as the longest plate worked on the mill. This permits two plates to be in the furnace at one time. Sometimes several furnaces of shorter lengths are used for each mill, but usually two furnaces of greater length are required for handling the output of one jobbing mill. The bottoms of the furnaces always have an outside slope from charging door to discharging door, in order that the plates can be more readily charged into the furnace and dragged out from the opposite end. This type of furnace always worried me, as it appeared that an unnecessary amount of labor was required for charging and drawing purposes. The majority of you are no doubt familiar with this furnace.

At the time the new plant of the Otis Steel Company was constructed, a continuous open-annealing furnace was installed. This was very interesting to me, as it was something I had looked forward to for a long time. I paid particular attention to the work, and after this furnace was put in operation found that the unique principle used gave every sign of being satisfactory. The new departure consisted principally of refractory rollers supported by water-cooled axles. These rollers were of such design that their refractory surfaces were always of the same temperature as that of the heating chamber. The running of water through the shaft was only for the purpose of keeping it cool, and it was insulated so the water would have no cooling effect on the surface of the rolls. No black spots of any kind appeared on the surface of the plates. A pinch roller was provided on the charging end of the furnace, as well as on the exit end, these pinch rollers being operated by power the same as the rollers inside the furnace. The shafts of all rollers extended through the side walls where bearings were provided, and the rolls were driven by chain and sprocket, operated by a variable-speed motor of the reversing type. The use of this furnace eliminated to a large extent the labor required for the old type, and permitted of the furnaces being built much longer than those previously used. The annealing qualities are far superior; there is no labor required for dragging the plates through the furnace, and tonnage can be easily

doubled with a very substantial increase in efficiency. This furnace is known as the Costello open-annealing furnace. Since the first installation at the Otis Steel Company's plant, this furnace has been taken up by the Canton Sheet Steel Company, the Western Reserve Steel Company, the Brier Hill Steel Company, and the Newport Rolling Mill Company. There was no complaint whatever regarding the operation of these furnaces, but it was found that the refractory rollers would not stand up any great length of time. As you will note, they were subjected to every element that would cause their failure; for instance, abrasion, vibration due to sprocket drive, changes in temperature—and all these in addition to carrying the actual load of the charge. The difficulty experienced was in retaining the brick around the axles. The brick used were side-arch brick beveled on each end and held in place by cast-steel disks which were also beveled. The width of the furnace governed the number of disks and circles of side-arch brick. Expansion and contraction had to be provided for, and this was accomplished by sliding a pipe sleeve over the water-cooled shaft with a spring on the outside of the shaft next to the bearing to take care of the tension and allow for contraction and expansion. The brick, however, would spall and crack, and as I had considerable to do with the designing of this furnace I spent a lot of time endeavoring to overcome the difficulty. I found it was not really a question of getting the proper refractory material and, to make a long story short, the trouble was finally eliminated by the use of a certain refractory cement. We experimented with every refractory cement that was brought to our attention, and all of these cements were of some benefit, but the one that proved entirely satisfactory appeared to go into working condition much sooner than the others and upon closer investigation we found that this cement really had welded the joints and welded them at a temperature of between 1000 and 1200 degrees F. It was found that a chemical of some kind used in this cement caused a slight flux to occur at the above temperatures. The flux was almost instantaneous, and actually made one solid mass of the brickwork, so that the joints were stronger than the brick. Due to the use of this cement there has been no further trouble with the rolls. This type of furnace for this particular class of

work is certainly worth the consideration of anyone requiring open annealing of either sheets or plates, as it is far superior to the old-fashioned furnace.

Speaking of furnace cements; if you will permit me to digress for a moment, I will mention an experience that I had some time ago that may be of interest to some of you who are operating hammers in proximity to your furnaces.

The furnace had just been rebuilt and ordinary fire-clay used in laying up the work. An inspection disclosed the fact that at each stroke of the hammer, the fire-clay descended in a shower from the joints. At the end of a few hours the joints between the bricks, especially in the crown, had been jarred out for a depth of 1 to 1¼ inches. A good, high-temperature cement would certainly be a wise investment under conditions of this kind.

I have now covered the heating of light stock for rolling purposes and will make some mention of heavy stock. In designing a furnace for heating heavy ingots for forging and press work, the stock is usually brought to a temperature of 2000 to 2100 degrees F. If it is special alloy steel the heating conditions are considerably different from those required for ordinary material. Special alloy stock is charged into a practically cold furnace and brought up to its working temperature very gradually, to prevent, as far as possible, surface cracks. When surface cracks do appear the temperature is then brought up to a wash heat or welding heat, whereby the cracks can be readily closed. It is preferable, from the manufacturer's standpoint, to use a furnace in which a wash heat can always be procured. With certain stock of alloy steels, such as billets and slabs that can be rolled, a continuous furnace would be ideal, as the charging end of this type of furnace is usually around 700 to 800 degrees F., but the ordinary continuous furnace cannot be used on account of not being able to procure a wash heat and at the same time prevent the stock from coming in contact, which would naturally result in it freezing or welding together. I will not dwell on this type of furnace for alloy steels, but will take this up later in a furnace that I consider unique for the purpose. In designing a heating furnace for heavy work—for instance, a furnace used by such

concerns as the Erie Forge Company, where it is common practice to heat ingots up to 62 inches in diameter—the design must be such that the stock, which is often of considerable length, can be heated in sections. This requires a furnace of considerable height so that the flame or gases can pass below the stock as well as above it. The time required to heat material of this size is figured out in our office in the following manner and based upon our actual practice: An ingot 62 inches in diameter, having a radius of 31 inches, requires the furnace temperature to be maintained at around 2000 degrees F. This temperature will permeate to a depth of ⅛ inch in five minutes, and 31 inches being equivalent to 248/8, this multiplied by five would give 1240 minutes—or 20 hours and 40 minutes. I find that with a stoker-fired furnace, the fuel consumption for this class of work runs between 700 and 750 pounds of coal; this rule holds good for all heavy stock. In order that the ingot may be heated in sections, a large opening is provided on each side of the furnace. The ingot is set up on a pedestal support on the outside of the furnace. If the end is to be heated, a cast-steel block is placed on the hearth for end support. Doors are not used on this type of furnace; but after the ingot has been charged, the openings of the furnace are closed up with brick, and sealed. For work of this nature a 12- to 18-inch space is allowed between the ingot and the hearth, and a 10- to 12-inch space between the top of the ingot and the crown. If the ingot is of smaller diameter than the maximum size for which the furnace is designed, the extra space is always left at the bottom instead of at the top. There are no special features connected with the design of this type of furnace, excepting that the combustion area must be sufficient to heat readily the maximum sized stock. A waste-heat boiler is usually built in connection with this type of furnace, and provision made to by-pass the boiler, so the furnace can be operated independently, when desired.

There is a type of heating furnace used for forging and press work which was designed for 16 by 16-inch ingots. Instead of this furnace being charged or drawn until it was either full or empty it was desired to keep the hearth full at all times—that is, immediately after a hot ingot is withdrawn, a cold one is charged to take its place, thereby utilizing the hearth area continuously;

precautions being taken to prevent a cold ingot affecting a hot one. A common hearth furnace was used, with a continuous bridge wall at the rear and one common combustion chamber beyond the bridge wall. The front of the hearth is provided with three or four doors and a partition wall run straight through the hearth of the furnace from the center of each door-jamb to the bridge wall and up to within a few inches of the skew-back line; thus dividing the hearth into compartments, with one common crown over all three or four compartments. These dividing walls prevent a cold ingot from having any effect on a hot one which is ready to draw. The plan works out very nicely and is highly recommended. Without the dividing wall it would mean that the whole furnace would have to be emptied before a cold charge could be made. It was figured that two of these furnaces could be used, instead of three with the common hearth, and the same tonnage produced.

I am going to end with a short discussion of a furnace that comes under the subject, "Continuous Furnaces for Wash Heat." At the time I mentioned this to Mr. Treschow, your Secretary, we both smiled over the heading, it being a well-known fact that it is next to an impossibility to run a wash heat in continuous furnaces. Of course, it is possible to do this if the stock is kept separate, but since this requires hand manipulation, every one who has so far attempted it has always gotten into serious trouble. The instant any of the stock comes in contact when under wash heat temperature it immediately becomes frozen or welded together. I remember one case where a concern sent out specifications to the various furnace contractors calling for a continuous furnace which would work a certain percentage of stock under wash heat. At the same time a specification was sent out by the same concern for a continuous box annealing furnace. I put in my bid on the continuous box annealer and thanked the concern very kindly for the opportunity of bidding on the continuous heating furnace, refusing to bid on account of what I considered the foolish specification calling for wash heat. Fortunately I secured the order for the continuous box annealer, and this put me in an excellent position to keep my eye on the operation of the continuous furnace that was to work under wash-heat conditions.

As I expected, it turned out to be a failure in every respect. From that time on I have kept the idea in mind and have tried to get out a real and truly continuous furnace whereby the stock could be kept separated from the time it was charged into the furnace until drawn. Unfortunately I have so far been unable to erect one of these furnaces. As you will note in Fig. 4–5, this furnace

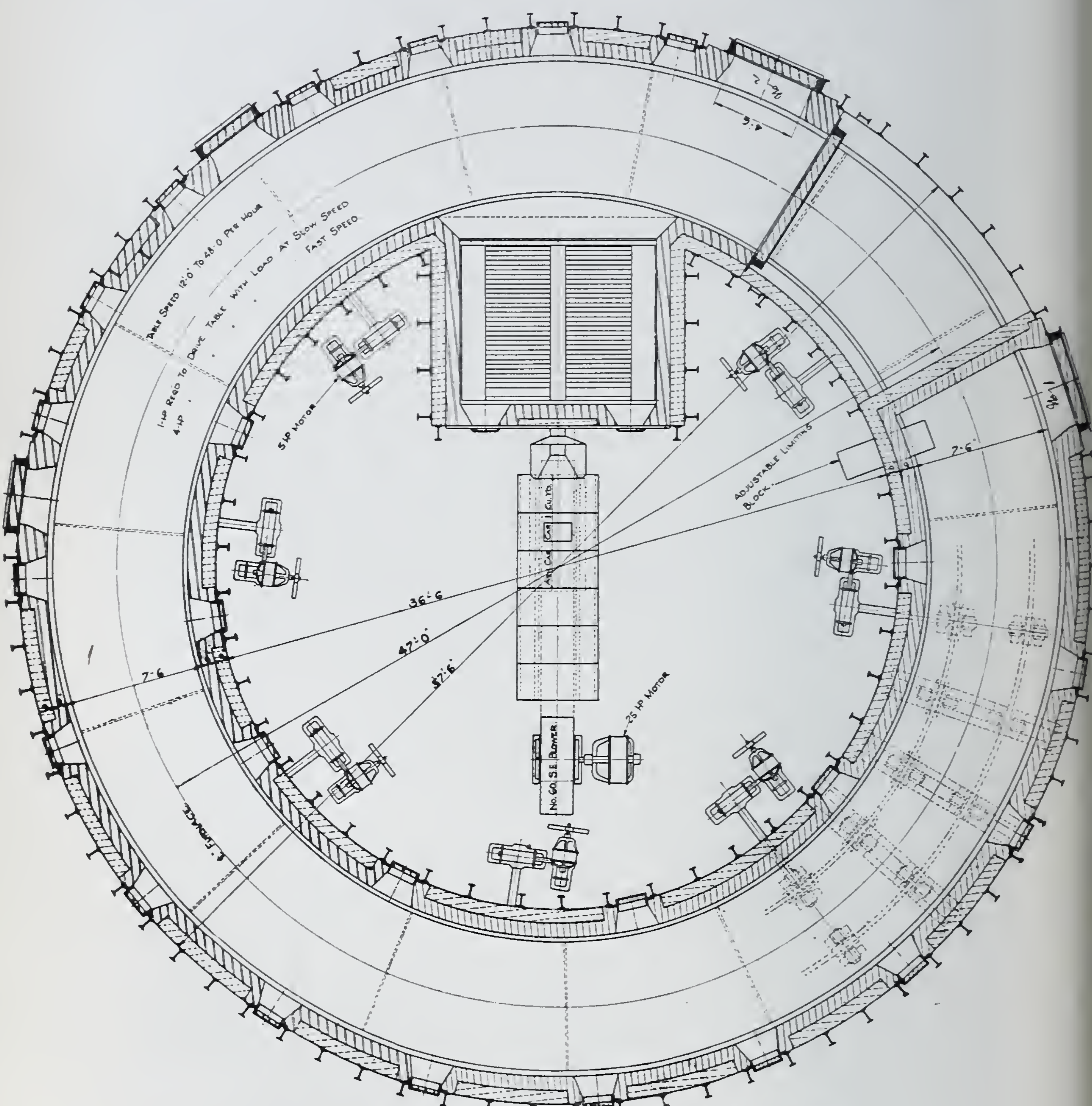

Fig. 4. Continuous Rotary Heating Furnace. Plan.

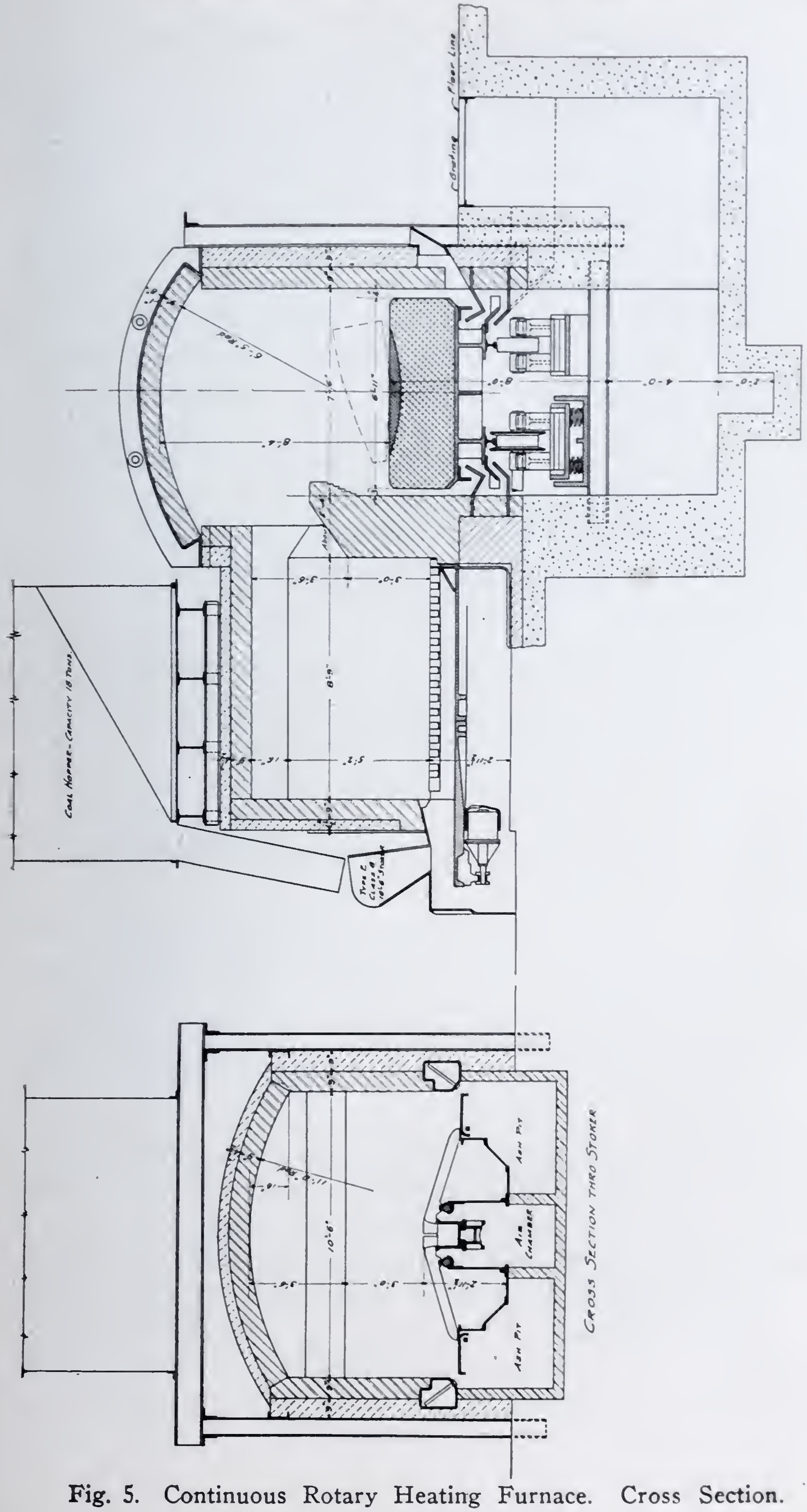

Fig. 5. Continuous Rotary Heating Furnace. Cross Section.

is nothing more nor less than an ordinary continuous furnace built in a circle. Car type bottom is provided with proper sand seals and the right clearance between side walls, and the necessary provision is made for taking care of any slag. This particular drawing was made to meet the specifications that were put out by the Ordnance Department of the United States Steel Corporation for the Neville Island plant and was intended especially for the handling of the large 4000-pound shells. This particular shell is of such design that when laid down it tips toward the tapered end. The shell is composed of special alloy steel and should not initially be subjected to a temperature much over 500 degrees F. By the use of a furnace of this description a preliminary heating furnace would not be necessary, and only one handling and one type of furnace would be required. A space which has no crown or side walls is provided, so that the bottoms can cool down sufficiently for special alloy steels to be charged thereon, but in ordinary practice where the material can be charged into a heating furnace this space is not necessary. In designing this furnace I have attempted to embody the following features:

1. To secure a continuous furnace where a billet could be charged into a temperature not exceeding 500 degrees F. and gradually brought in contact with increasing temperatures until a wash heat was reached.

2. A furnace into which a billet of special alloy steel could be brought up gradually to a wash heat, handled only once, and not be in any danger of coming in contact with the next billet.

3. A continuous furnace for wash heat that would permit of ordinary hearth repairs being made without interfering with its operation.

By the design of the crown I have assured the even distribution of the gases, and prevented them short-circuiting or hugging the inner wall. The crown is made in sections of the bung-arch type to permit of quick and easy repairs; the bottom section can be readily removed and a new one placed at the opening provided for this purpose; slag is taken care of in a way that I consider would prove very satisfactory; all moving parts are easily accessible for inspection and repairs. There are a dozen other points about this furnace—such as control of heat, prevention of air

infiltration, etc.—which have been given careful consideration. It has been tried out on a small scale and is now in use in St. Louis, but on very light work.

I feel that I have already trespassed too much on your time. If there are any questions you care to ask me, I shall be pleased to answer them to the best of my ability. I would especially like to hear as much criticism as you care to make of the furnace I have just shown you. This type of furnace is bound to be put in use and, inasmuch as I am likely to be the "goat," it would not do me any harm to have some of my ideals shattered now while they and not my pocketbook are at stake.

In conclusion, I want to assure you that I sincerely appreciate the honor you have done me by extending me this invitation. I only wish I had felt more nearly equal to the occasion.

DISCUSSION

Mr. W. E. Moore:* I notice that this special ring, car-type furnace has been provided with cars which do not carry the usual traveling wheels, but have the wheel journals fixed rigidly on the foundations. That design would probably be an objectionable feature. The segmental trucks on the cars would bump on those wheels and it would be a difficult thing to keep up the sand seals under the cars. If you have some special reason for this method, an explanation would be interesting.

Mr. George J. Hagan: Quite a few of us had a hand in getting up this particular design, and the only reason I recall for not putting the wheels directly on the cars was the mode of transmitting the power. You notice the outside wheel is without flanges, to take care of expansion. Certain wheels are idlers, the driving shaft going through the walls from the motors on the inside circle of the furnace. I know the question was brought up as to whether we would get more vibration, thus in any manner affecting the seals, but we felt that by properly lining them up we might be able to avoid it. It has not been tried out, and no doubt a lot of problems would develop which would have to be worked out.

Mr. W. E. Moore: What would the furnace cost?

Mr. George J. Hagan: When the estimate was made, that furnace ran $268 000. I am not prepared to say that I will build the furnace on trial under those conditions.

Mr. W. E. Moore: In the continuous sheet-bar type furnaces do you find it necessary to use any special steel for the floor troughs?

Mr. George J. Hagan: No, except that it is a cast-steel proposition. We have found by experimenting that cast-steel will not grow as rapidly as gray iron.

*President, W. E. Moore & Co., Pittsburgh.

Mr. W. E. Moore: I have found in stoker work that it is quite an advantage to have cast-iron that is low in silicon. It is the silicon that causes the growth resulting from repeated heating of cast-iron, as in grates, furnace irons, and pipe fittings for superheated steam.

Mr. George J. Hagan: We have not tried a cast-iron bottom. We started out with a cast-steel proposition. As I stated, in the first place we did have some trouble with warping but by further experimenting we were able to get results such that the weight of the charged material practically held the bottom in shape.

Mr. W. E. Moore: Do you push the sheet bars through the furnace with axes inclined to the vertical?

Mr. George J. Hagan: Yes, on an incline of 45 degrees.

Mr. W. E. Moore: What prevents the lower ends of bars in contact with the steel furnace hearth from being cooled?

Mr. George J. Hagan: When the bottom once gets its heat, the charge is in so long that we really carry the bottom at the same temperature as the charge.

Mr. H. A. Kunitz:* Do you calorize the bottom?

Mr. George J. Hagan: No. We have had that under consideration. I know of some concerns that have tried some annealing boxes and have had fairly good results, but I have not been able to find out whether or not it would justify the extra cost.

Mr. W. E. Moore: In that connection, I have seen a spring-tempering, continuous-type, automatic furnace—with carrier chains traveling over the furnace hearth—which worked very well. They at first used nickel-chromium and other alloys for the chain links, but finally settled on monel metal, which was much cheaper than "nichrome" and about as cheap as "calorized" steel.

*Assistant Chief Engineer, Crucible Steel Co., Pittsburgh.

MR. A. F. MITCHELL:* What kind of high-temperature cement was found to be best?

MR. GEORGE J. HAGAN: I would be glad to answer that question, but I want to make some excuses. At the time we found this particular cement I found it was manufactured by a concern which I think did not realize that it had a product of such quality. I visited this company afterwards with an object in view, and I do not wish to make an advertising medium of this paper. (Voices: Go ahead.) I would not mention it without permission. It is known as the "Adamant" brand, sold by the company with which I am connected. There is a peculiar quality connected with it, and whatever may be the chemical used, it changes the thing so that there is great difficulty in discovering what the cement contains. I could not discover it by visiting the manufacturing plants, which I have done several times. I know this much about it—the base is really ground crucibles, ground as fine as possible in a grinding mill and then put in a ball mill, with water added until it comes out in a plastic state. I know all cements of this nature contain a large percentage of silicate of soda, and I know that is added to it; but from there it goes into a little secret room such as you used to hear about in the old days and this chemical is added. I have heard several other concerns say they have attempted to analyze this cement, but have failed to determine its composition. I have made one or two tests and have found that the cement has been welded as low as 930 degrees F. Laboratory tests show that a flux occurs almost instantaneously—very mild, but just sufficient to weld itself to the surface of the brick. I know this particular cement is paying the expenses of every salesman we have on the road. Probably Mr. Moore knows the fusing temperature.

At the plant of the Farrow Spring Company, I went into the superintendent's office and made my request about watching the crown in the electric furnace. They had only a two-inch crown. I had never heard of that thickness of crown holding up during operation of the furnace. I asked the bricklayer about it and he said he would show me a curiosity, and he also informed me that I

*Metallurgical Engineer, Ordnance Department, U. S. Steel Corporation, Pittsburgh.

was responsible for it. They let me try to get a good view of that supposed two-inch crown. I could not see the crown, but I saw a peculiar formation like a honeycomb, the honeycombed structure being "Adamant" cement. Maybe Mr. Moore knows at what temperature that electric furnace operates and what the extreme temperatures are; I do not. A testing laboratory at one time reported 3600 degrees F. as the fusing point of "Adamant" cement.

Mr. W. E. Moore: In the electric arc type of furnace, the arc temperature is always far in excess of the fusing temperature of refractories. The refractories stand up only by reason of the fact that a part of the heat flow is conducted through the refractory wall to the outside. It is necessary to leave the side walls uninsulated from the furnace shell or leave them exposed so that the refractories conduct away as much heat as possible from the inside of the furnace where heated by the electric arc. The temperature of the electric arc is around 6500 to 7000 degrees F., which is much above the breakdown temperature of any refractory known to the art.

The furnace roof frequently fuses and drips, forming stalactites, and the inside of the roof then represents a honeycombed appearance. This is only another indication of the inevitable wearing away of the refractories. The fact that the roof crown of the furnace will stand up when only two inches thick shows that the brick on which the special mortar was used have been pretty well cemented together.

I happen to know that the men selling patented, trademarked, high-temperature cements at fancy prices, are making them out of the cheapest material. One very popular cement sold at $80 per ton is made of old burnt-end silica brick ground to a powder.

Mr. H. A. Kunitz: How do you take care of the expansion of the hearth ring 45 inches in diameter, and what is the clearance between the side walls?

Mr. George J. Hagan: We would have to make the hearth of that particular furnace out of special blocks that would dovetail

to take care of expansion and contraction. The details of that particular point were not all developed, but I think it would be a simple matter to work out those features.

Mr. H. A. Kunitz: Then it is not a continuous ring?

Mr. George J. Hagan: No. It is all made in sections, as I said.

Mr. F. L. Egan:* In the circular continuous furnace at the stoker end, I judge you would have quite a plus pressure over the moving ring. How are the sides and ends of the moving blocks sealed to prevent the hot gases from passing into the lower compartment?

Mr. George J. Hagan: We have taken into consideration that we are possibly going to get a considerable plus pressure at that point, which would no doubt cause inconvenience every time the door is opened. Therefore, we developed a mechanical arrangement so that when the door is opened it automatically controls the air flow to the stoker.

Mr. F. L. Egan: I was thinking more of the seal of the blocks. That seal is made with sand, I suppose. Are the dovetail joints between the blocks also sand sealed?

Mr. George J. Hagan: Sand sealed, but with just direct contact on the bottom.

Mr. Moore mentioned the fact that the wheels were not on the car itself. That recalls to my mind that this particular furnace of the Allegheny Steel Company had a stationary bearing on the wheels, but after the furnace had operated about a year they changed that arrangement and found it was better.

Mr. W. E. Moore: In furnace combustion, what do you find to be the best velocity of gases passing through the heating chamber?

*Engineer on River Equipment, Carnegie Steel Co., Pittsburgh.

Mr. George J. Hagan: I have never given that much consideration, but in certain work we try to keep the velocity down as low as possible.

Mr. W. E. Moore: That means large combustion chambers, of course.

Mr. George J. Hagan: Yes. The old type of furnace used to have a high velocity compared with what we are now using, and it had a pitting effect on the material.

Mr. W. E. Snyder, *Chairman**: Professor Trinks, we ought to hear from you.

Prof. W. Trinks:† Since you call on me, I will ask a few questions. First, in your opinion, how does powdered coal compare with the American stoker for sheet and pair furnaces?

Mr. George J. Hagan: At one time I was in the powdered coal game but, never having secured an order, my experience is very limited. I might state that powdered coal is now installed at the plants of the Standard Tin Plate Company at Canonsburg, Pa., and the Newport Rolling Mill Company at Newport, Ky. The latter company has been operating two burners in some of my combination furnaces. There are, no doubt, a few things in favor of powdered coal rather than the stoker—but very few. One, which we must admit, is that the work can be done on less fuel. I find it takes 300 to 325 pounds of powdered coal per ton of finished product of the tin mill. In stoker practice we do the same work with from 350 to 375 pounds. Comparing the saving between the amounts of coal required with powdered fuel and with stokers, and adding your cost of pulverizing (and I have never yet found a cost of 40 cents in pulverizing coal, and I know of one plant where the cost is $1.10) you will find the saving in dollars and cents in favor of the stoker.

I would like to be able to mention some facts and figures which were given to me recently, at a plant not very far away,

*Mechanical Engineer, American Steel & Wire Co., Pittsburgh.

†Professor of Mechanical Engineering, Carnegie Institute of Technology, Pittsburgh.

of what it is actually going on and the troubles they have been up against. I do not want to condemn powdered coal, and from what I have seen and been able to learn, it appears that powdered coal is an important factor, especially in high-temperature work; but I have good reason to doubt whether it wll ever be a success in the lighter gage materials or with lower temperatures such as in tin mill and sheet mill work.

I have not yet found a plant which will admit a saving over what we can show with stokers. The American Rolling Mill Company at Middletown, O., operating on stokers, is an exceptional one. The furnace contract was placed with me. They got up their own specifications and they really went to extremes. They used anywhere from 4½- to 9-inch heavier walls than was the custom in good practice; much heavier buildings; cast-steel corner plates for furnace bindings, instead of structural shapes which would have answered just as well; a very elaborate system of coal-conveying apparatus, and all kinds of devices to check up and weigh coal. Not only that, but they have a system of keeping track of the coal used in each mill. A blackboard is placed once a week with a star for the man that secures the lowest coal consumption; and the figures which they have given me from month to month, taking a general average, have always been so low I am ashamed to go after a prospect and use the figures. The average is 218 pounds of coal in sheet mill practice per ton of finished sheets. It may be that if that same concern had powdered coal and used the same technique they could show the same relative saving, but so far they have always refused to consider powdered coal in the sheet mill end of their operation.

The main trouble I notice in some of the powdered coal installations is lack of proper control. That may be due to several reasons—perhaps the system they use in conveying coal to the burners, or perhaps the type of burner used.

MR. R. E. WAGGONER:* I did not hear the first part of the paper, but I should like to ask if anything has been done in designing furnaces for liquid fuel such as coal tar?

*Chief Steam Engineer, Upper Union Mills, Carnegie Steel Co., Pittsburgh.

Mr. George J. Hagan: I have had no experience with liquid fuel. I think there are one or two gentlemen here who could answer that, as they have gone into it quite extensively.

Prof. W. Trinks: You stated that with oil firing there was pitting of the sheets. Have you any explanation of that?

Mr. George J. Hagan: This matter was first called to my attention several years ago by representatives of the Inland Steel Company. They were endeavoring to make an automobile stock sheet and they had a considerable amount of pitting on the surface of the sheet. At that particular time they changed superintendents. Oil was going up in price and the new superintendent, who was familiar with stokers, wanted to see oil thrown out and stokers put in. That was before we could point to any great number of installations.

In the early days where I met a concern which was not familiar with our proposition, but which had a plant that looked like a good bet, I would make extra inducements to put in and handle installations without cost, but I could not arrange that with the Inland Steel Company, as things were very dull. I found that the cost of their heating on sheet and pair furnaces seemed to be very high. I then made a proposition to take their heating by contract. They did not want to spend the money for stokers, so I made a proposition to remodel the furnace and install stokers and do the heating by contract for a period of years, at the expiration of which the equipment was theirs. We went so far as to back up the proposition with a bond, and I secured an order to install one furnace.

But to get back to the question, I never discovered the real reason, but after the pitting of material was first brought to my attention I made it my business to visit plants that were using oil, and I invariably found that complaint as soon as they got into the problem of a sheet with a high-finish surface, though in those days but few of them attempted it.

Prof. W. Trinks: I have observed oil firing in many places. Now, there are great differences in oil burners, and with some oil-

fired furnaces I have seen a great many sparks flying out through the door, and upon investigation have found that they were simply drops of oil that were still burning, and it occurred to me that there might be drops of oil from a wrongly designed burner that would land on the sheets and cause pitting; just as with powdered coal we occasionally find some coarse particles floating through the furnace and causing trouble.

Mr. George J. Hagan: I should not be surprised. I know the Inland Steel Company did, at that time, experiment extensively with various types of burner.

Prof. W. Trinks: I want to ask whether there is a general rule as to when a waste-heat boiler should be installed?

Mr. George J. Hagan: We have not done very much in that direction. We have had inquiries from customers as to whether they would be justified in equipping a furnace with waste-heat boilers. In one or two cases our power plant department has recommended it, and I believe in just as many cases has condemned it. I really cannot answer the question as to what the rule is regarding the volume of gases or the continuous time the furnace may be worked.

Mr. W. E. Snyder, *Chairman*: The only rule I know anything about is that it depends on whether there is enough heat going to waste to justify the expenditure necessary to reclaim it, and the economizer can be put in in such way that it will fit into the system and it does not require an operating force or a licensed man, for instance. It is purely a commercial proposition. You have to measure the temperature of the gases and the approximate volume and get at the average from day to day, and see how the installation required to reclaim the heat will fit into the existing system.

Prof. W. Trinks: I figured just that way in one plant, but it did not work out at all. The heaters insisted that all of the flame should come out through the door, and they practically closed up the flues leading to the waste-heat boiler. What is the right thing to do in such a case?

Mr. H. E. Gross:* In what direction does the flame travel from the stoker to the stack? As I understand it, the natural course for the flame to take in a circular tunnel-shaped furnace is the shortest course to the stack connections.

It is considered very important on wrought-iron heating furnaces, that the temperature at the drawing side be somewhat higher than at the back wall.

Mr. George J. Hagan: As I said before, imagine a straight-away continuous furnace. The flame takes the same direction except that it travels in a circle.

Mr. H. E. Gross: Where does the flame pass out of the furnace to the stack?

Mr. George J. Hagan: At the charging end of the furnace.

Mr. Erich Zademach:† Is there any special way of laying brick, or any other approved method of preventing a furnace from "growing?" The "growing" or expansion frequently results in destroying the alignment of piping and machinery, and I should be glad to know if in your experience you have developed any remedy which is more satisfactory than the well-known expedient of placing sawdust (to be burned out later) in the spaces between the bricks?

Mr. George J. Hagan: There are certain refractories which have greater expansion than others. We did build a set of furnaces for the Latrobe Steel Company in the time of Mr. Griffiths, a very particular man, and he ordered quite a number of thin strips of wood. I forget how many brick we laid before we would put in a strip and break it off, and I really did find that they did not have to tighten and loosen buckstays as much as in the ordinary furnaces. Of course silica brick were used; I have never seen anything of that kind used with the ordinary clay refractory brick.

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†Mechanical Engineer, American Steel & Wire Co., Pittsburgh.

THE PRACTICAL OPERATION OF INDUSTRIAL BOILERS

By W. E. Snyder*

INTRODUCTORY AND GENERAL

I have hesitated a good while before finally deciding to write a paper upon this subject. My hesitation was due partly to the fact that there has been a great deal written upon various phases of this matter during the past three or four years, especially during the past year on account of the coal shortage, and any discussion which I might make would seem like threshing over threshed straw. I have also hesitated because I believe we have come to look upon the address of a retiring President as something out of the ordinary line of technical literature, while this subject is so commonplace it has ceased to arouse much interest. Because of these considerations I believe that I should preface the main discussion by an explanation of my reasons for giving it, and also state clearly its limitations. Before I read anything, particularly technical literature, I usually try to find out who the writer is, and what his experience and equipment are to warrant his writing the paper. Sometimes it is unnecessary to go any farther.

For over 22 years I have been directly engaged, as part of my work, in the operation of boiler plants. For about 17 years of this time I have had general supervision of a large number and variety of plants, consisting at present of 42 boiler plants, containing 465 boilers, aggregating about 146 000 rated horse-power. During my earlier experience, I did about every kind of work that a man can do with or about boilers, in the way of firing, cleaning, repairing, inspecting and operating them. I have had experience in the use of almost every kind of coal there is in this country, and with about every kind of accident that can happen to a boiler. When I think over my earlier experiences, I am fully convinced that the only reason why I am permitted to stand

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here alive and address you, is because a kind and ever watchful Providence preserved me from the consequences of the carelessness and ignorance then so common in boiler operation. In from six to eight instances which occur to me, I escaped what might easily have been serious or fatal injury, without being hurt in any way and through no special ability or knowledge on my part. For though at that time I was a graduate of a good technical course in engineering, I did not have the practical knowledge which comes from experience to enable me to take proper precaution against the dangers continually present in the operation of the older boiler plants; and what is more important, the men who had practical experience and some knowledge of boilers, knew no more of safety rules than I did, if as much, and took risks and maintained conditions which to-day would not be tolerated for one hour.

It would serve no good purpose and take up time to discuss the various conditions which used to exist in boiler plants, and which were a continual menace in one form or another to the men who had work to do about the boilers. These conditions resulted from insufficient knowledge and study, on the part of the designers of the boilers, those responsible for their installation and those in charge of their operation. A boiler plant used to be a place where nobody would go if he could avoid it, and if he did go, he would not stay any longer than he could help. It was the darkest and dirtiest and most congested place around the whole works, and the most dangerous types, two-flue and return tubular boilers, were in common use, because of their low first cost and because there was no good way to clean out the inside of tubes of water-tube boilers.

The study given to the whole subject of boiler engineering during the past few years has resulted in a very great improvement in boiler plant design—at least in all those plants operated by large companies with which I am familiar. There must, however, still be considered the ever present and always important matter of safety to lives and property, and my experience has emphasized over and over again that in this line of work, as also in some other engineering lines, there is no such thing as a little thing. Every detail is of importance, and the best boiler manufacturers and engineers of the country now realize this, as is evi-

denced by the attention given to all the minor details in the design of the boiler and its setting. However, it is of no use for engineers and boiler manufacturers to give attention to such details, unless corresponding attention is given to the details connected with the installation of the equipment of the boiler, which is necessary to operate it properly, and to its daily service. There must be consistency in making provision for safety and reliability, in everything about the steam generating plant proper, together with the necessary knowledge on the part of the men who are responsible for handling it in order to insure the maximum possible degree of safety.

So much for safety in operation. Next in importance to safety is economy in the use of fuel. In my earlier experience, practically no attention at all was paid to this, nor to the economical use of steam and power. The only object was to generate steam enough to keep the engines running and, so long as this condition continued, the boiler plant was doing all that was required. The development of a new order in manufacturing, which resulted among other things in complete cost sheets, soon emphasized the importance of efficiency in the use of coal. For a number of years past I have been vitally interested in every phase of this matter of improvement of fuel economy—with varying degrees of success. It is easy enough to effect economy in coal by compounding and condensing simple non-condensing engines; by replacing wasteful small engines and pumps by motors and motor driven pumps; by eliminating wasteful transmission machinery by the use of motors, etc., but when it comes to effecting any large and permanent improvement in boiler efficiency, where so much depends on the knowledge and work of the men directly in charge, the problem is entirely different in character.

I have said enough in the foregoing to indicate why I have selected this subject. The question of safety has always seemed to me so important that too much cannot be said upon it. The problem of economy of fuel is every year becoming of increasing importance. I cannot hope to discuss this matter of economy exhaustively, as the local conditions at every plant vary so much, but I do hope to present some phases of it, in a helpful way, which

will stimulate discussion by others with a result that will be beneficial to all.

The boiler plants referred to in this discussion are those of blast-furnaces, large steel-works and other large heavy manufacturing plants. The efficiency of such boiler plants will range from 50 to 60 per cent. Sometimes it is under 50 per cent. and sometimes it may run as high as 65 per cent. The plants contain from 5 to 30 boilers, of from 200 to 300 horse-power rated capacity each, in some plants as high as 500 horse-power per unit. The firing is done by hand on flat grates; or chain-grates, or inclined grate stokers are used. The boilers may have been in service from 8 to 25 years, with different types and sizes in one boiler plant.

Where the plant has reached such an age that its replacement is necessary, the problem is not so difficult, for the reason that modern boiler plants, which are economical in labor and efficient in the use of fuel, can be installed. However, even in such modern boiler plants, the problem of operating the boilers at high efficiency is a difficult one, owing to varying manufacturing conditions which cause the steam demand to fluctuate widely, and to the low-grade labor available; but it is with the older boiler plants, mainly, that this discussion has to do—plants that are too good to be replaced, and yet of such character that their efficiencies are low.

I have had a number of experiences in the past where boiler plants of this kind were severely criticized by those interested in smoke abatement and such other public movements as we have been recently experiencing connected with the economy of fuel. This criticism often emanates from men who have good general engineering experience in the use of fuel and the production of steam, but almost no practical experience with the ordinary workaday conditions of operation in such boiler plants as these. On the face of it, the conditions often look bad and justify the criticism. Efficiencies are low, many of the men in charge know very little about their work, and the general impression given by the whole plant is unfavorable. I have been criticized by good conscientious engineers for defending such conditions. I did defend them, not because they were right, but because I know more

different phases of the situation than did the critics. Such conditions have a business as well as an engineering side. To install a new boiler plant under prewar conditions would have cost $50 per horse-power and during the past two years from $120 to $150 per horse-power, depending on the equipment installed.

If the existing boilers have been made safe to operate, by attention to such matters as are discussed herein under the head of Safety, the only reason for replacing them will be economy of fuel and labor, and many times it is not possible to justify the expenditure necessary for the replacement by the saving in these two items which will result. This is the business side of the matter. When it is not possible to justify replacement of boilers for safety reasons or because of the economy which will result, they must be operated, and the only criticism that can be tolerated refers to the particular point as to whether or not the best results possible with the equipment are being obtained.

To judge whether or not the boiler plant is giving as good economy as should be obtained, requires an intimate knowledge of all the conditions under which the plant operates—the kind of fuel used; the kind of grates, stokers and boilers, and the way they are installed; the operating conditions of the steam using equipment, and the kind of labor available. Some of these factors are not under control of the plant management at all. About all that can be done with the coal is to see that its quality is kept up to that covered by the contract, and that it is properly prepared for the furnaces using it; the kind of grates, boilers, etc. is fixed, at least for the time being and cannot be changed; the works must operate to produce the kind of product, and in the quantity required, at the particular time, and the boilers must supply the steam to do this; the character of the labor force operating the boilers is the only factor that is really under the direct control of the plant management. Even here there is the great handicap of limited labor supply, frequently changing; sickness, etc., necessitating the use of inexperienced men, who often do not understand the English language well enough to be taught anything. All these conditions make the operation of the older boiler plants an extremely difficult proposition, and oftentimes render the comments of the impractical critic unjust.

In new boiler plants with the best modern equipment installed in accordance with engineering practice of the present time, the situation is much more favorable to good results. In this case, labor saving devices reduce to a minimum the number of men necessary, but the men must understand their work and perform it properly, or high efficiency is not possible, even with good equipment. Some phases of this labor problem and the training of the men are considered under the subject of Economy in this paper.

SAFETY

During the past few years, owing to the development of safety work in manufacturing plants, the safety features of boiler plants which are necessary to their proper operation, have become well standardized. There are now on record and available for easy reference a number of rules and recommendations, a large part of which the writer has aided in preparing, which cover the important points that should be given attention to provide for the proper safety of lives and property. (See Paper on "Industrial Engineering Safety" by D. S. Beyer, PROCEEDINGS, vol. 28, pp. 143-165.) It may not be amiss, however, to mention here briefly some of the most important safety features of boiler plants, keeping in mind that this discussion applies mainly to existing plants of the older type:

Boiler Insurance and Inspection—First and most important is boiler insurance, with the incidental inspection by trained boiler inspectors which always accompanies such insurance. It is perhaps unnecessary to argue in favor of boiler insurance at this time, as all large companies with which I am familiar carry it. The benefits which result from periodic inspections by men whose sole time is taken up with such work, and who in consequence acquire an experience which makes them very keen detectors of defects, are so great that they cannot be over-emphasized. While this is true of the regular inspections made by boiler insurance companies, there is an additional advantage in having the benefit of their expert advice in case a condition develops which may make it necessary to take a boiler out of service temporarily and

immediately, or when it is necessary to decide whether boilers shall be repaired or replaced. These are questions upon which it is not possible to bring to bear too much expert knowledge and experience, as the risk involved in a wrong decision is out of all proportion to the mere money cost of the insurance.

Local Inspection and Records—Next in importance to the regular inspections by the inspectors of companies specializing in boiler insurance, are the local inspections which should be made by some designated engineer or experienced mechanical man connected with the operation of the boiler plant. Such inspections should be made much more frequently than the inspections of the insurance company representatives, and should cover all of the conditions of the boiler, its setting and piping, etc., which have to do with both safety and economy. That is, the inspector should be provided with suitable clothes, so that he can get into the drums and into various parts of the setting and carefully examine the riveted seams, tube connections and pipe connections, etc., with respect to safety; and also examine the interior of drums and tubes, and the outside of heating surfaces, conditions of baffles, etc., with respect to economy. Examination by the local inspector covering all conditions favorable to good economy is of special importance, because the inspection by insurance company inspectors is only required to cover such matters as have to do with safety. The insurance inspector has primarily in his mind the safety of the boiler under pressure and if he calls attention to anything which has to do with economy it is mainly because of his desire to be helpful in the proper operation of the plant. For this reason the local inspector should keep in mind both safety and economy while doing his work; also, it should be an established rule that every time the local inspector makes a complete examination of a boiler and its setting, he should write a complete memorandum of his inspection, giving the date and the number of the boiler, even though there is nothing special to report. Such a memorandum is of great advantage in case an accident occurs and it becomes necessary to make a thorough investigation. Such an investigation will bring out every item of information, which has to do with the condition of the boiler on which the accident occurs, for years past; and if in addition to the file of reports of

the insurance company's inspectors, there are the regular and complete memoranda of the local inspector's examinations, the small amount of additional work which devolves upon the local inspector in keeping such written reports of his inspections will be well repaid.

Inspection of Pipe Systems—Next in importance to the inspection of the boiler and its setting by the local inspector, should be his inspection of the feed, blow-off and steam piping systems. Such an inspection does not need to be made as often as a boiler inspection. Possibly once a year is often enough for a complete examination of piping, but such an examination should be made, and it should be made by some one who knows enough about these conditions to know when they are wrong. It should also include the different valves and their condition. In such inspections of piping we have found and removed a large number of dangerous features, such, for instance, as cast-iron sections in main steam lines and in feed lines; copper bends, corroded threads on blow-off connections; 10-inch and 12-inch steam pipes with threaded end and blank flanges screwed on, so that the full steam pressure acting on the flange had to be borne by threads cut years before; thin flanges, out of all proportion to the pressure carried; flanges in which some of the holes did not coincide, and two or three bolts were left out, etc. These and various other defects, too numerous to mention, oftentimes hidden by pipe covering, are revealed by systematic inspection of piping.

Stairways and Platforms—A proper system of stairways and operating platforms, with railings and toe-boards is absolutely necessary to good operation. It is not possible to make detailed suggestions in a matter of this kind, because the local conditions are different in every boiler plant. It should be kept in mind, however, that stairways are necessary for easy and quick access to the parts of the installation above the floor level, and that these stairways should be arranged so that in case of an accident it is hardly possible for a man to be trapped with no means of getting down to the floor. The platforms and walks should be planned so that all the main valves, water columns, manholes, cleaning doors, etc., are easily accessible. This is necessary, not alone from

the standpoint of safety, but to insure reliability and economy in operation. If cleaning doors and manholes cannot be reached except by old wooden ladders and planks, as used to be the case, it is a foregone conclusion that the men will use them only when they cannot help it.

Cast-Iron Under Pressure—Most of the older boilers were constructed with cast-iron parts, such as mud-drums, headers and pipe connections. Cast-iron under steam pressure is always dangerous and when, in addition, it is subject to strains due to the heating and cooling of the boiler and its connections, it is doubly so. It is not always possible to eliminate the risk incident to the use of cast-iron, but it can be minimized. Cast-iron or cast-steel mud-drums are often dangerous elements. Wrought steel mud-drums are now made, which it is practicable to attach to older boilers, and which are entirely safe. Wrought or cast-steel headers can also be used to replace cracked cast-iron headers, though a broken header is not usually a serious matter like a cracked cast mud-drum. Where the flanged connections on a boiler are subject to heavy strains, such as may be due to the connection of main steam-pipes, safety-valves, etc., the cast-iron can be replaced by cast-steel. Of course it requires the use of judgment and common-sense in deciding how far to go with the replacement of cast-iron in boiler plants which have been in service a number of years, as it depends on the condition and probable remaining life of the boilers and whether there is any apparent weakness. In my opinion cast mud-drums ought to go first, if there is a possibility of continuing the boilers in service for even a few years.

Non-Return Valves—Automatic or so-called non-return valves are important safety features of any boiler plant. This type of valve, together with a gate-valve placed between it and the main steam header, with proper prevention of water pockets, makes a very good and safe arrangement. The automatic valve closes in case of accident to the boiler, thereby isolating it from the remainder of the steam system. We have had dozens of instances of tube failures or header breaks which allowed a sudden drop of pressure in the boiler, and invariably this valve immediately closes. By the use of a small connecting line and pilot

valve for each automatic valve it is possible to make these valves close in case of a break in the steam-pipe system which allows the pressure to drop, and in this way shut off every boiler, but accidents of this character are not so common as those to individual boilers, which allow a sudden pressure drop in any one boiler. The automatic valve also serves an important function, after pressure has been has been raised in a boiler and it is ready to be connected to the line. In this case it is necessary only to open the gate-valve in the branch pipe any time while the steam pressure is being raised in the boiler; then as soon as the pressure in the boiler is sufficiently high, the non-return valve is automatically opened by the steam pressure, and the boiler in this way placed in service. This eliminates the operation of opening by hand the valve which permits the steam being generated in the boiler to enter the main steam system; which was sometimes dangerous, due to an accumulation of condensed steam in the branch pipe forming a water-hammer when the valve is opened, and knocking the side out of the valve or a fitting. I have known serious and fatal accidents to result, due to this cause, when boilers were connected to the line, and the use of the non-return valve, as explained, avoids the necessity for a man to be on top of the boiler while it is being "cut in."

Feed-Water Regulators—Feed-water regulators are important adjuncts in the operation of boilers. The earlier types regulated in such a way that the feed valves were either shut or wide open, and they are unfavorable to good operating conditions. The most satisfactory type adjusts the valve to any position between closed and wide open, so that the water admitted to the boiler is always just sufficient to supply the quantity leaving the boiler as steam. This makes the change in the rate of feeding the boilers much more gradual, which is the condition most favorable to safety and good economy. The function of the regulator is not to replace the water tender but to relieve the water tender of the extremely troublesome detail of continually adjusting feed valves. This is no small task in a boiler plant having from 10 to 20 boilers, in various stages of generating steam, and when the water tender is relieved from this continuous performance of manipulating valves, he can devote his whole attention to the supervision

of the water-level of the boilers. The water tender is always an experienced fireman, and he should combine the supervision of the fires with that of the water-levels. This he can do the more easily when the feed-water regulators control the supply of water to the boilers. It is perhaps unnecessary to add that each boiler should be equipped with the best water columns obtainable, and that these columns have gage-glasses and three try-cocks, operated by rods or chains from the point most convenient for the water tender. Working around water columns, or replacing gage-glasses when the boiler is under steam, is always dangerous, because of the liability of the glass to burst, causing injuries to the face and particularly the eyes. For this reason only the highest class gage-glasses should be used, and these protected by guards. We have, by the use of high-grade gage-glasses, divided the former number of breakages by six, averaging for a whole year throughout a large number of plants. This, of course, reduces the liability to serious accident in the same proportion, and the proper use of guards still further reduces this. There is no telling how many cases of blindness of one or both eyes have been prevented by attention to a comparatively simple detail of this kind.

Safety-Valves—Attention to the kind and capacity of safety-valves is a very important matter. It was formerly the custom to put on boilers of a certain capacity a safety-valve, or two valves, without anyone knowing anything as to how much steam the valves would discharge per minute. In order to protect the boiler properly, the safety-valves should have sufficient capacity to discharge the full quantity of steam which the boiler will generate with the main steam outlet closed. Safety-valves as now manufactured have a guaranteed discharge capacity under specified conditions, and in this way it is possible to be sure that there is enough valve area on every boiler to make the conditions safe. Also, the valves should be tried every day, in order to be sure that they work freely. This is a very simple matter, and does not take much time if proper provision is made for it.

ECONOMY

In the general discussion at the beginning of this paper, reference was made to the importance of the labor problem in connection with the operation of boilers, whether old or new. This refers particularly to the boiler foremen who have charge of the plants, to the firemen who have charge of the firing of the coal or the operation of the stokers, and to a less extent to the men who clean the boilers inside and outside. Boiler house foremen must be thoroughly instructed regarding the side of their work which has to do with efficiency, and taught that their sole duty is not just to keep up steam pressure. Some systematic plan must be followed to train the firemen, so that they will know when the fires are in proper condition for best economy, and when they are not.

During the past two years a great deal has appeared in the technical press, and in papers before engineering societies on the subject of fuel economy. The intention of the writers is good and much of the discussion is helpful, but my criticism has always been that this discussion is usually too academic and fails to get at the real heart of the matter, by failing to give proper importance to the training of the operating men of the plant. The assumption seems to be that the superintendent of the works has the power to create to order an operating crew for the boiler house which will be of high-grade intelligence, coupled with an enthusiasm for the work which will only make it necessary to post a series of typewritten rules in a few conspicuous places to insure safety and high efficiency. As a matter of fact, many boiler plants are operated under the charge of boiler house foremen who used to be water tenders, and are still water tenders in their knowledge of the work, with enlarged duties. The water tending is done by men who used to be firemen, and the firemen were formerly ash men or flue blowers, most of whom have been recruited, not very long before, from the ranks of laborers. In their work they have acquired a certain familiarity with the stokers, boilers, pipes, valves, etc., with which they have to deal, but they have practically no knowledge of the methods of operation which it is necessary to follow to save fuel and labor.

There is no use in becoming disgusted with the general lack of intelligence of such a boiler house crew and firing them all out. This would result only in getting together, after much effort, another and different set of men, with about the same general characteristics and abilities. We know how to set boilers properly to use coal efficiently; the problem is to operate the boilers, day after day, so that present-day engineering knowledge will be utilized by the men directly in charge.

A military organization would not get very far in accomplishing its purpose, if the staff officers, after frequent and elaborate discussions, developed a system of setting-up exercises, manual of arms and tactics of maneuver, which would be used only for further discussion in the officers' school. The military unit is made efficient by training individuals in accordance with scientifically established principles. Results would never be accomplished by allowing bunches of privates to drill as they might, with an officer to lecture or scold them at intervals.

So it is in a somewhat similar way with the operating crews of boiler plants. They must be trained and the problem is how best to accomplish this training. In order to make some useful suggestions on this point, it is necessary to discuss briefly the losses of fuel or heat which take place when coal is burned under a boiler. The best way to improve efficiency is to reduce the quantity of heat lost. However, in order that the coal may be used efficiently it should go to the boilers properly prepared, and this phase of the subject deserves a little special discussion.

Preparation of Coal—Only the coals used in the Western end of this State are referred to—i. e., those from the Pittsburgh, Upper and Lower Freeport, Upper and Lower Kittanning, and Brookville seams. Under normal operating conditions at the mines, the operators try to produce clean coal, by various systems of fining the miners who load dirty coal, and by having hand pickers on the cars to throw out the biggest chunks of slate as the coal is loaded. If there be any laxity on the part of the consumer, owing to a large demand for coal, the result is an increase of slate and dirt in the coal. Only continued inspection, accompanied by occasional trips of the inspector to the producing mines will keep down to a minimum the incombustible matter which the coal contains.

In general, it does not pay to use the so-called ¾-inch screened coal, which costs more than the straight "run-of-mine." The screen at the mine is usually made of narrow steel bars, placed ¾ inch to 1 inch apart and at an angle of about 45 degrees. The openings between the bars soon become clogged up with small pieces of coal, so that the screen is not much more than a chute, and takes out only a part of the slack. Coal for chain-grates and inclined grate stokers ought to be crushed so that the largest lumps will pass through a one-inch ring, and then the fuel burns out uniformly by the time the fire reaches the back end of the grate. The best way to prepare coal for furnaces of this kind, at a plant where there are gas producers, is to pass the "run-of-mine" coal though a coarse crusher, so that the largest lumps are broken down to a size of four- or five-inch cubes, then pass the crushed coal over a rotating or shaking screen of about 1- or 1¼-inch mesh. In this way the screening is far more effectively done than it is when passed over an inclined bar screen. All the coal that goes through the screen is the kind best adapted to boilers while the coarse coal that goes over the screen is just right for gas-producers, locomotives and miscellaneous hand-fired furnaces.

The coal coming from the different mines of this section does not vary as much in the results which it produces, as the coal from the same mine may vary, due to carelessness in mining. I once made a series of 29 tests, carried out in every detail, as completely as such tests can be made. Each of these tests consisted of five 24-hour periods, each period in itself being a complete test, during which the boiler was run at a different capacity, varying from the rating of the boiler to 60 per cent. over rating. Coal from 21 different mines and five different seams of this section was used, This coal was fired by intelligent firemen, on flat grates, under a Stirling boiler of 275 horse-power. Some of the coal used was the so-called ¾-inch screened; and yet, notwithstanding the difference in the grades and the mines and the seams, the overall efficiency of boiler and grate for the entire series of tests varied only between 59.6 per cent. and 63.5 per cent., or a difference of 3.9 per cent. This means that only 6.5 per cent. more of the poorest coal would be required than if the best were used—all comparisons being made on a dry coal basis.

Heat Losses After Coal is Fired—When coal is fired into a furnace, the potential heat which it contains goes to one of four places:

1. Into the boiler.
2. Up the stack.
3. Into the ash-pit.
4. Into the air surrounding the boiler setting and piping.

Only the heat which enters the boiler is useful; that which goes to the three other places is wasted. If these three sources of waste are dealt with separately, it simplifies the subject so that it is more easily comprehended by men without knowledge of theoretical principles.

The heat lost up the stack may vary from 15 to 35 per cent., and the reduction of this loss is the most important step in improving boiler economy. This loss is due to:

(a). Excess air.
(b). Sensible heat.
(c). Incomplete combustion.
(d). Moisture in coal.

Excess air is the air which is heated from the temperature of the furnace air supply to the stack temperature, and passes through the boiler without the oxygen which it contains combining with the combustible elements of the fuel. It is due to holes in the fire or openings at the back end of chain-grates; thin fires; leakage between the brickwork and the metal parts of the boiler and its setting; open doors, etc. The reduction of this excess air is most necessary in improving economy. The most important work of the fireman in reducing this waste is to keep the grates evenly covered with a fire thick enough to utilize the oxygen in the air coming through, the best condition having been determined by analysis of the flue-gas; also having the furnace doors open as short a time as possible when firing coal or working with the fires.

The leakage of air through any opening in the setting other than those into the furnace proper is an especially bad condition, for the reason that this air has no chance whatever to combine

with the combustible elements. It simply acts as a carrier of heat to the stack. There is a variety of compositions on the market, used for coating over the brickwork itself to make it impervious to air, but we have never derived any benefit from their use, though careful comparative tests have been made. It is hardly possible for air to leak through a solid brick wall 18 or 22 inches thick, when the vacuum inside is only slightly below atmospheric pressure. It is entirely practicable to plug permanently the small openings and cracks in the brickwork through which air can pass into the setting. Ill fitting cleaning doors have the same harmful effect as any other openings into the setting, which is not the case with doors opening into the furnace, as a little air over the top of the fire is often a benefit.

The total sensible heat carried away in the products of combustion is due to their temperature above that of the entering air. This waste is increased by the gas passages through the boiler being too direct; by holes in the baffling; dust on tubes and other heating surfaces; dirt and scale inside the boiler; too much forcing, etc.

For the gas passages being too direct, the design is responsible and not the operating men. If it is not possible to put in additional baffles, it is necessary either to run the boilers as they are or to install economizers, which we have done in one plant of vertical water-tube boilers, with a very substantial return on the investment. Sometimes boilers give very good efficiency when they are new and the baffling in good condition, but after they are used awhile and it becomes necessary to replace tubes, the baffling is partially wrecked in the process and the hot gas short circuits through the broken baffling. In some boilers with cross baffles it is extremely difficult to repair these baffles properly, and this is my main objection to boilers with baffling perpendicular to the tubes. If the tubes become bent or warped in service and have to be driven out, there is more work in repairing the baffles than in replacing the tubes. It may be that the most modern boilers of the cross-baffle type have improved baffling, but I refer here, as in other parts of this discussion, to those of the older design.

The development of mechanical flue blowing equipment is a splendid improvement. I do not think it is ever possible to keep

the heating surface of boilers clean outside by hand blowing, as it is almost an impossibility to reach some parts of the boiler and there is too much opportunity for the men to slight their work.

The use of mechanical flue blowers not only keeps the heating surface cleaner than hand blowing, but it avoids opening the doors of the setting frequently and thus allowing large quantities of air to be drawn in. Also, these doors never fit tightly and the cracks around them have to be repacked every time they are used, which is often done in such a way that there is a continuous leakage of air. Although these beneficial results follow the use of mechanical blowers, I do not mean that all hand cleaning is eliminated. When a boiler is off for cleaning, it ought to be inspected and the heating surface swept or blown off wherever necessary.

Even with the most conscientious work in cleaning the fire side of the heating surface, the tubes often become coated with a thick layer of very fine dust, tarry or sooty deposit, which it is not possible to blow off. This is a splendid insulator, and the worst trouble to deal with that I know of in keeping the boilers perfectly clean. Mr. Joseph Harrington, Administrative Engineer, Chicago District, United States Fuel Department, recently sent out a letter stating that this deposit can be completely cleaned off by the use of common salt. For an ordinary boiler, two or three large shovelfuls of salt are thrown over the top of the fire and the furnace closed up. It is said that this completely cleans the heating surface, and that two years' use had caused no harmful effects whatever. Of course this treatment does not have to be used every day, but only when the condition of the tubes indicates the presence of the deposit mentioned. It is a simple remedy, which is apparently effective and is worth careful trial.

There is not much excuse now for dirt and scale inside of a boiler. Where it is necessary to use water that is permanently bad, either due to acid, or suspended or scale forming matter, a water purifying plant is the only solution. However, even with a water purifying plant, some scale will form in the tubes, but there are thoroughly good turbine tube cleaners now made with which it is possible to clean the tubes completely; the only thing necessary is to be sure the cleaner is the right size for the tube, as, if it is too small, the men will push it through without cutting out all

the scale. Before these tube cleaners were developed, I have seen four-inch boiler tubes filled almost solid, and scale 1 to 1½ inches thick was common, but there is no longer any reason for such conditions, if even the most ordinary supervision is exercised. In this connection it is important that the boiler house foreman inspect personally every boiler after it is cleaned. The inside of the tubes of some boilers cannot be examined except by the inspector getting into one drum and an assistant with a light getting into another. This is where the instruction of the boiler house foreman must come in.

The heat loss due to excessive forcing is not usually continuous, and sometimes has to be permitted in order to tide over an emergency. Where it is continuous, the remedy is of course more capacity.

Moisture in the coal as it comes from the mines varies considerably, but for a number of mines in the Pittsburgh vein, this ran about 1.4 to 2.9 per cent. from a number of mine samples taken. From mines in other seams of this district it ran from 3½ to 10 per cent. What it is when delivered at the boiler house depends on the time it was in transit and the weather conditions, but it usually contains more than the mine moisture. Additional moisture is often added before it is fired on chain-grates, and this is the moisture I refer to particularly. We have made tests which show that dampening fine slack fired on chain-grates, so that the total moisture content was from five to eight per cent., improved the efficiency and capacity as compared to firing the slack dry, but the great trouble with this is that too much water is likely to be put on. I have seen the coal literally soaked, so that the moisture which it contained ran from 16 to 20 per cent., and this is wasteful. Of course, theoretically, any moisture in the coal must be evaporated by the heat in the furnace, requiring 970 B.t.u. per pound of water. Then each pound of water passes up the stack as superheated steam at the temperature of the flue-gas, and in this way any moisture carries away heat from the furnace. Therefore, adding water to coal would seem to be providing a means for carrying away heat uselessly. However, a small quantity seems at least with some coal, to improve combustion and prevent clinkers, and in this way the resulting benefits are greater than

the actual heat loss caused by the water. However, it does not follow that increased benefit will result from increased water and, when water is used at all, it should be in such a way that the coal cannot be soaked.

The incomplete combustion loss is due to firing too much coal at one time; too thick a fire; clinkering coal and insufficient combustion space and temperature.

Firing too much coal at one time, is a practice that must be dealt with mainly with hand-fired boilers, as there is not much reason for trouble of this kind with stokers. I have seen so-called firemen put in over 700 pounds of coal in a furnace of a 300 horse-power boiler at one firing, I verified this by counting the shovelfuls and weighing several. After this most interesting display of intelligence, the firemen will sit down and smoke for some time. Since the coal contains at least 35 per cent. volatile matter, there was about 250 pounds of rich hydrocarbon gas in the furnace, a large part of which would be distilled off and passed up the stack without being consumed. Of course this is an exaggerated case, but it illustrates a practice which exists in many boiler plants. This is one great advantage of any good mechanical device used for firing; it feeds the coal gradually and continuously to the fire—something which it is almost impossible to make a fireman do in this district.

I do not know of any way to determine the proper thickness of fire for a given hand-fired grate or stoker, with the draft available, other than to run tests with different thicknesses and analyze the waste gas. Of course the ideal condition is very low oxygen, indicating minimum excess air and no CO. This is true with any kind of fuel—coal, blast-furnace or coke-oven gas. It is usually impracticable to determine hydrogen or hydrocarbons in flue-gas, and it is assumed when there is no CO present, that combustion is complete, which may or may not be true. I fully believe that the heat loss due to incomplete combustion is much greater than indicated by the presence of a small quantity of CO, especially when the coal is not fired uniformly, because the CO indicates that there is incomplete combustion, and there is, therefore, a strong probability that hydrogen and the hydrocarbons which are not detected by the waste gas analysis are passing out unburned and these gases are very high in heating value.

Clinkering coal causes incomplete combustion, by the ash in the coal melting and forming a thin layer on top of the grate-bars, which prevents the air from passing through. The inexperienced firemen attempt to relieve this condition by free use of the slice-bar; pushing it under the fire over the grate and turning the fire upside down. This mixes the clinker among the burning coal, where it again melts and fuses the coal together, making a mess which will not burn at all. When using coal with an ash of this kind, fired on flat grates by hand, the less disturbance of the fire the better. As soon as the grates begin to cover over, the fire must be burned down as well as possible, and then cleaned. There is no use in trying to keep the grates open by using the slice-bar, as it only makes a bad condition worse. Such clinkering coal can usually be burned successfully on chain-grates by running a thin fire and letting the fire alone, cleaning any clinker, which does form, off the grate as it comes around.

As boilers used to be set, the space for the combustion of the gas above the fire was entirely too small. Sometimes the heating surface was not more than a foot or a foot and a half above the top of the fire. This results in the hot gases impinging on the comparatively cool heating surface of the boiler while they are in process of combustion, which lowers the temperature of the gas so that its combustion is not complete. This results in an extremely wasteful condition, one evidence of which is the formation of smoke. We have tried various expedients to overcome this trouble, without actually resetting the boilers, which in most cases is either not practicable, or would be so expensive that the outlay would not be justified. We have in some cases changed the baffling on cross-baffled boilers to horizontal baffles, and lowered the bridge wall, thus utilizing the space back of the bridge wall for combustion. In this space piers and wing walls are built to serve the purpose of mixing the gases. The results are beneficial so far as the abatement of smoke is concerned and in improving combustion, but there is additional difficulty in keeping the surface of all the tubes clean on the outside and keeping the additional brickwork in repair.

However, all such changes are only expedients, to be adopted as such for the purpose of carrying over the boilers until such

time as their age and condition require replacement. The importance of large combustion space and high temperature in that combustion space cannot be emphasized too much. One boiler company recommends, from investigations which they have made, two cubic feet of furnace space per rated horse-power, using blast-furnace gas, and for coal 1½ to 2½ cubic feet of furnace space per rated horse-power. Another boiler company that has been developing larger furnaces has had good results from 3 to 4½ cubic feet per rated horse-power.

High temperature in the combustion space and thorough mixture of the oxygen with the combustible elements are favorable features of the underfeed type of stoker using forced blast. I have always considered the principle of feeding the coal uniformly underneath the fire and burning it with forced blast as a most efficient means of using bituminous coal. This is indicated by a paper which I read before this Society December 19, 1899 (PROCEEDINGS, vol. 15, pp. 333-360). When to this method of feeding and burning the coal is added large combustion space, so that combustion is nearly completed before the hot gases come in contact with any considerable area of the heating surface, the results are bound to be good—provided of course the boilers are kept clean and handled properly in other ways discussed herein.

I have discussed above at considerable length the losses which take place up the stack, as they are by far the most important and their reduction will effect the greatest saving. The loss in the ash-pit must be dealt with in different ways, depending on the type of equipment used. With hand-fired grates, about all that can be done is to have the air spaces in the grates as small as is consistent with proper air supply. I like best the herringbone bar, with the air spaces not over one-half or five-eighths inch wide. With flat grates the most of the unburned coal falls through near the front end, where it is often possible to scrape out some of this before the fires are cleaned, and fire it over again. With chain-grates it is usual to extend the floor of the boiler room back under the grate about two-thirds its length, or put in reclaiming pans extending back this distance. All the unburned coal that falls through on this can be raked forward and refired. All the coal that is not burned out when it reaches the back end of a chain-

grate is dropped over with the ashes and cannot be reclaimed, and it is for this reason that it is important to have coal used on chain-grates crushed fine, as is discussed above under Preparation of Coal.

It may not be amiss to say a word in regard to sampling the contents of the ash-pit for analysis, to learn what the loss actually is. It is not possible to get a fair sample of a large quantity of mixed ashes and clinker. What I like to have done is to have all the clinkers of any size picked out with a hook and weighed separately. This is incombustible and does not need to be sampled. The remaining ashes, which will be mostly fine and easily handled, can be weighed and then sampled in the regular way. The combustible part which this contains can then be determined as a percentage of the total contents of the ash-pit.

The loss of heat to surrounding air does not need any very extensive discussion as the proper remedy is apparent. This, of course, is to cover every part of the surface of the boiler, piping, valves, etc., with a good thick non-conductor. The use of insulating brick, as one vertical course inside the boiler wall which surrounds the hottest part of the furnace and boiler, would, I believe, be warranted by the heat saving which will result, though I have not had much experience thus far in their use. We have used such brick in the walls of other kinds of furnaces, and careful tests show that the heat radiated through the walls is only 50 per cent. of what it was with the same kind of a wall without the insulating brick. In a boiler installation recently completed we find about the same reduction in radiation.

Training of the Men—Having discussed, above, the various heat losses which take place in operating boilers, it remains to discuss the application of this in the training of boiler house foremen and firemen. I believe the best way to begin this training is to prepare a typewritten or printed manual of instructions for boiler house foremen. These instructions must be given in clear and simple language, and then passed to the boiler house forman by the superintendent or works manager, with the request that he study them carefully, in the expectation of being examined on them later. After the boiler house foreman has had sufficient time to become familiar, to the extent of his capacity with the

instructions, an engineer or other mechanical man familiar with the subject must take up with the boiler house foreman these instructions in detail, explaining to him the points which he does not understand, and learning from him the particular kind of difficulties with which he has to contend in carrying out the instructions. The main purpose of all of this is to be sure that the boiler foreman understands what should be done to improve boiler efficiency, so that when conditions are not right, it will be known at once that it is due to carelessness and not ignorance, which it is very important to know in fairness to the men. This study by the foreman, with discussion following, must continue until he understands fairly well what is required.

After the foremen have received such preliminary training as has just been mentioned, the next step is to teach them more in detail about the proper handling of the fires. This is so that the foreman will be properly equipped to instruct the firemen verbally and by actual example as to what to do to keep the fires in proper condition. In this further instruction of the boiler house foreman, I believe one good method to follow is to equip one boiler in the plant completely with recording instruments and teach him the use of these instruments for the purpose of controlling the fire and the boiler. After the boiler house foreman has a good working knowledge of the curves drawn by the recording instruments, he should be required to rotate the firemen, so that the boiler equipped with the instruments will be under the charge of each fireman successively, for several days or a week at a time. While each man has charge of the boiler, he must be shown the effect of the different operating conditions as indicated by the curves of the instruments, and he thus gets at least a fair idea of what he is required to do in order to keep down the waste of heat.

The kind of instruments referred to, all of which are recording, are the following, considered as a minimum: A steam-meter, showing the rate at which the steam is leaving the boiler; a recording pyrometer, with the thermo-couple located as explained by United States Bureau of Mines Bulletin No. 145; a draft-gage, with one connection to the furnace and the other to the flue between the boiler and the damper; and a CO_2 recorder, which gives

a fairly continuous record of the carbon dioxid in the flue-gas. These instruments are mainly for the purpose of reducing the loss up the stack, where the greatest saving can be effected. The contents of the ash-pit from this same boiler should be sampled, and this result, together with those from the pyrometer and the gas analyzer, used in comparatively simple calculations to determine the total percentage of heat wasted, omitting radiation which is fairly constant from turn to turn. This gives a line on the actual results produced by the boiler, which is close enough for all practical purposes and can be posted for each turn in any form desired, to arouse the interest of the men.

In general, I do not believe in equipping each boiler, in a boiler plant of the kind under discussion, with a variety of instruments such as these mentioned. Such instruments are of no use whatever, unless they are kept in fairly accurate condition and the information which they give actually used in handling the fires. It is no small task to keep instruments of this kind in proper adjustment so that they will give reliable information and, when a number of boilers are completely equipped, the work of keeping the instruments in good condition can easily be out of all proportion to the benefits which result. It should be kept clearly in mind that such instruments are of no use whatever unless they have a favorable effect on the cost sheet. The owners of some boiler plants buy such instruments and have them installed for the same reason that some people give money to the church—they feel a sense of obligation to do something; they therefore seize upon the thing that is most convenient, and having satisfied their consciences pay no further attention to the matter.

Two examples of this have come to my notice within the last three months: Owing to the earnest efforts that have been made by the United States Fuel Administration, a great deal of interest has been taken in improving the operation of boiler plants, and the manufacturers of various kinds of instruments used in operating boilers have been very active. The representative of one such manufacturer gave us the names of companies using his instruments, and some written testimonials from these companies emphasizing the benefits which resulted. We sent an experienced man to investigate. He found the instruments installed all right,

but some of them were not in condition to use; the boiler house foreman did not have clearly in mind what benefit was to be obtained by their use, and the firemen were handling the fires without any reference whatever to the instruments. In the other case, one of the inspectors aiding the United States Fuel Administration stated that the questionnaire from one plant indicated conditions so good as to warrant the maximum rating of 100 per cent. All boilers were equipped with various kinds of scientific instruments, stationary tube blowing apparatus, etc. He found later, however, on visiting the plant that neither the instruments nor the flue blowing apparatus had been receiving any attention at all, and were in such bad condition that they could not be used.

Therefore, I would repeat that when such instruments are installed in a boiler plant, they should be put in as forming part of the regular operating equipment of the plant and used in operating the boilers. If this cannot be done, they had better not be put in. The conditions about the ordinary boiler plants of steelworks or blast-furnaces are such that it is difficult to keep these instruments in proper condition, and it is better to have one boiler fully equipped and kept in condition and used for instruction purposes, than to have all the boilers partially equipped and allowed to get out of adjustment and become inaccurate so that the whole thing becomes a farce.

I would qualify the above discussion of instruments in this way: If I were installing a first-class modern boiler plant of large units, say 800 or 1000 horse-power each, I would consider very seriously the equipment of each boiler with instruments. In a high-grade modern plant of this kind, the operating conditions are considerably different from what they are in the older plants with smaller units, discussed in this paper. The principle mentioned before should, however, be kept in mind in this case—that is, put in no instrument unless it is to be regularly used in the promotion of either safety, efficiency or reliability.

Comfort and Convenience—Next in importance to better provision for safety and proper and systematic training of the operating men, are good working conditions. The boiler house ought to be made as comfortable as it is possible to make a place of this kind. There should be good light, both day and night, good venti-

lation and some attention should be given to keeping it warm and free from drafts in the winter. It may seem an anomalous condition to speak about warming a boiler house, but as an actual fact many times boiler houses are cold and drafty when the weather is cold. It must be kept in mind that, on account of the enormous quantity of air required to burn the coal when a number of boilers are in operation, the boiler house cannot be made tight; there must be provision for this air to get to the furnaces. The only proper way to deal with this condition of comfort of the men, is for some one who is familiar with operating conditions to make a careful inspection, both by day and at night.

It is necessary to make such provision for convenience that the work which the men do may be done as easily as possible; otherwise they will slight it as much as they can. For instance, furnace doors which have to be opened at intervals for firing or to inspect the condition of the fires, should have wooden handles, and if these are not possible, the metal handles should be wrapped with wire-woven asbestos sheet, or other non-conductor. If it is not possible to inspect the fire through the doors, small inspection windows should be put in, made by running through the wall a two-inch pipe, with a glass window in its outer end. A piece of blue glass four or five inches long by 1½ inches wide, set in a frame with a handle on it, in the hands of each fireman, or a number of pairs of blue glasses distributed where they will do the most good, are, in my opinion, mighty good aids in handling the fires. The right kind of firing tools are also necessary. I have often seen firemen try to do their work with tools which were entirely unsuited for the purpose. Possibly the handles were too long, where the space is limited, and the handles were made of solid iron rods three-fourths to one inch in diameter, where light pipe would serve every purpose. Such things may seem like petty details, but I have seen so much wasted energy, due to lack of attention to these very things, that I know their importance is not always appreciated.

Many boiler plants in this section are fired with various kinds of mechanical stokers and chain-grates. In order to control the fire properly, it is necessary to change the speed of these machines. In making this change of speed often one of the worst conditions

which exists is due to an arrangement of the driving mechanism, which permits the change of speed of several grates at the same time by the varying speed of the engine which drives them, and also an individual change of speed effected by changing the ratchets or point of connection of the driving-rod on each machine. This double provision for changing the speed makes it impossible for a fireman to know definitely what he is doing. For example, suppose he slows down the speed of one grate, by changing the driving ratchets. Some one comes along and slows down the speed of the engine driving this particular grate along with a number of others, and the result is a double reduction of speed on this particular grate. Or suppose the speed of the engine is increased by rising steam pressure or some other cause, the change which the fireman made in reducing the speed of one grate is partially or wholly neutralized by the increase of speed of the driving engine. Whatever the means for driving the firing mechanism or the grates adopted, the important thing to be kept in mind is that the speed of the grate for each particular boiler must be controlled independently of all others, and that the change of speed must be made at one place, and the fireman must know that the change which he makes will not be doubled or halved or completely neutralized by variations in the speed of the main driving shaft. If it is desired to have the speed of the main driving shaft changed by the operation of the pressure regulator, so that when the pressure rises the speed of all of the grates will be automatically reduced, this can be carried out all right and still maintain the conditions above mentioned. That is, the speeds of the main driving shafts will be changed automatically by the pressure regulator to suit the demand for steam, while the speeds of the individual grates will be changed by the firemen to regulate the condition of each particular fire.

The use of draft regulators is to be recommended where they are properly installed, and where the regulator will control the draft from the full effect of the chimney to a certain minimum, which is enough to keep the grate bars from burning. I have no use for a regulator which is either wide open or shut. The use of a draft regulator in boiler plants which have individual stacks on the boilers will mean quite a little actuating mechanism between

the regulator and the dampers. If this is not put in properly, with ball-bearings for the damper shafts, and every possible care taken to make everything work freely and smoothly, good results will not be obtained. The installation may work all right for a few months or a year, but after a while the attention required to keep it in operating condition is such that it is out of use most of the time. When it is necessary to operate the dampers regularly by hand, the lever by which each damper is controlled must be placed within easy reach of the fireman, with a rod or rope running to the damper. If it is necessary for the fireman to walk to the rear end of the boiler and hang on to an old piece of rusty wire every time the damper is to be changed, it is a certainty that it will not be changed very many times during a 12-hour turn.

The water going to the boilers should be metered, and the meter should preferably indicate three things—the rate at which the water is being supplied at any particular instant; a curve recording this rate of feeding on a chart, and the total quantity of water fed in a definite period of time. The information given by such a meter is necessary to the regular operation of the boilers, and in giving the actual results produced by the boilers during the month in definite units on which actual costs of operation and fuel used can be based. I think it is also advisable to use the results from this meter at the end of each 12-hour period in a memorandum, for the superintendent of the works, which shows the number of boilers in operation and the average horse-power developed per boiler for each turn. This has the beneficial effect of insuring that only enough boilers will be kept in service to meet the actual demand for steam when operating at the capacity for best economy. (See paper by John A. Hunter on "Operation of Boiler Plants of Industrial Works," PROCEEDINGS of this Society, vol. 27, pp. 287-318.)

Instruction Manual—In the foregoing discussion emphasis has been laid on the necessity for definite training of the men who directly control the fires and boilers. For this instruction we must depend mainly on the boiler house foreman as the men are under his direct charge. In order that the boiler house foreman may instruct the men properly, he must first be taught by means of the methods suggested above, using a simple manual of in-

struction as a sort of text-book, and the question arises, what shall be included in this book?

It may be said that there are now several good pamphlets which have been prepared by the United States Bureau of Mines and other similar agencies, explaining how to use coal efficiently, and this is true. The main difficulty is that these pamphlets, though very good for the men with a fairly good education, contain a little too much for most boiler house foremen; written as they are, to cover in general all kinds of conditions throughout the country. I would favor using such publications as a basis, taking from them what seems to be specially adapted to the conditions existing. For instance, some recommendations regarding the proper care of boilers and use of fuel, are suited to all boiler plants. These, however, must be supplemented by a number of others which are adapted only to the boiler plant in which the book is to be used. It may be a question as to whether or not the safety rules for the operation of boilers should be included. My own opinion is that if these rules do not reach the hands of the boiler house foreman through other channels, they should by all means be included in such a book as we are discussing. Also, I think there should be a part which explains clearly and in simple language the different instruments which are used in the particular boiler plant, and how they are to be used so as to be an aid in efficient operation.

I submit as Appendixes to this paper an Outline and several pages on Economy designed to serve as a basis for such a pamphlet. These are necessarily incomplete, and do not include any detailed suggestions relating to any particular plant, yet they may serve to indicate the style or method of explanation of the prevention of heat losses. The language is simple, so that if there are some firemen with sufficient knowledge of English, copies of these pamphlets or parts of them can be given to such firemen. Another essential feature is to have some pictures made, which, if the instruction book is typewritten, can be made by a good draftsman and blue-printed. These pictures will serve to make clearer some parts of the explanations; for instance, how best to use the steam lance when blowing dust off the tubes; the proper place for the fireman to stand when throwing coal into the furnace;

the appearance of the fire when it is in proper condition; other pictures showing wrong condition of the fires, etc. In other words, the boiler house foreman and the firemen must be taught to do their work properly; it is not possible to corner each man in succession and explain and lecture to him at intervals, and some systematic method must be followed, including the use of a pamphlet of instructions such as is being discussed. The exact contents of this pamphlet and the precise way it is used may be modified in any way to suit local conditions.

For aid in the preparation of such an instruction book as this, there is splendid and helpful information to be found in a number of existing publications. I have in this paper made references to three papers read before this Society. Among other very good papers are the following, though the list is by no means complete:

Harrison Safety Boiler Works, Philadelphia.
Finding and stopping waste in modern boiler rooms. 1918.

Hartford Steam Boiler Inspection & Insurance Company.
Suggestions for the care and management of steam boilers used for power purposes. (In *The Locomotive,* July 25, 1911, v. 28, pp. 193-208.)

Hartford Steam Boiler Inspection & Insurance Company.
Economy hints or thrifty suggestions for meeting the fuel emergency. 1918.

Kreisinger, Henry, *and others.*
Combustion in the fuel bed of hand fired furnaces. 1916. (*United States Bureau of Mines. Technical paper 137.*)

Kreisinger, Henry.
Hand firing soft coal under power-plant boilers. 1915. (*United States Bureau of Mines. Technical paper 80.*)

Kreisinger, Henry.
Saving coal in boiler plants. 1918. (*United States Bureau of Mines. Technical paper 205.*)

Randall, D. T. & **Weeks,** H. W.
Smokeless combustion of coal in boiler furnaces. (*United States Bureau of Mines. Bulletin 40.*)

Willard, A. C. *and others.*
Fuel economy in the operation of hand-fired boiler plants. 1918. (*University of Illinois Engineering Experiment Station. Circular 7.*)

There are also a number of good trade publications along the same line, prepared by companies manufacturing equipment used in improving efficiency in the operation of boilers.

In conclusion, I will add only this: Discussions by national and local engineering societies, of the fuel economy problem, are all right and necessary to stimulate interest and improve practice, but the interest should not stop with this. In the last analysis, fuel economy, with any given equipment, is effected largely by the men in the boiler plant. General engineering supervision alone is of itself insufficient. The men must be properly taught the details of their work as a fundamental basis of safety and efficiency. I hope that the means suggested herein as aids in their training will be a helpful contribution to a phase of this subject which, to date, has hardly received the attention merited by its importance.

APPENDIX 1

MANUAL OF INSTRUCTION FOR BOILER FOREMEN

(Suggested outline, to be changed or expanded to suit conditions and several copies made, with permanent binding, for each boiler house.)

PART I. SAFETY IN OPERATION

(For further details see PROCEEDINGS, vol. 28, pp. 156–165.)

Inspection
Safety-valves
Water columns
Steam-gages
Steam-valves
Stopping leaks under pressure
Cutting boilers into the line
Starting fires in a cold boiler
Checking fires
Blowing out boilers
Laying off boilers
Cleaning boilers
Cleaning boiler settings
Laying up boilers

PART II. ECONOMY

(See also Appendix 2 for suggested form.)

Where the Heat Goes:

1. Into the boiler
2. Lost up the stack
   - Baffles
   - Dirt on heating surface

Dirt and scale in boiler
Air leaks in setting
Fire too thick or too thin
Moisture in coal

3. Lost in ash-pit
    Repair of grates and furnaces
    Reclaiming coal that falls through grates
    Sampling ashes

4. Radiation
    Covering wherever possible

Firing:
    Quantity per firing
    Method of placing coal on fire
    Keeping fires level and free from holes
    Clinkering coal
    Method of cleaning fires
    Kind of tools to use

Boiler Capacity and the Load:
    Feed-water meter chart
    Use of damper
    Regulation of stoker and chain-grate speed
    Saturday night and Sunday load

Other Heat Losses:
    Low feed-water temperature
    Blowing safety-valves
    Leaking blow-off valves
    Steam leaks

PART III. LOCAL CONDITIONS

Pertaining only to plant in which book is used.

PART IV. PICTURES

1. Illustrating place for fireman to stand when hand-firing coal
2. Showing the distribution of coal over top of the fire
3. Showing too much coal piled in on front end of flat grate

4. Holes in the fire
5. Fire too thin at back part
6. Fire too thick at back end of chain-grate
7. Proper fire for flat grate
8. Proper fire for chain-grate
9. Cubes showing average quantity of heat to boiler, to stack and to ash-pit.
10. Kind of firing tools to use

PART V. INSTRUMENTS

(Illustrated if necessary.)

Description of each, and method of using it so as to improve results.

Feed-water meter
Damper regulator
Steam-meter
Gas analyzer
Pyrometer
Draft-gage
Steam-gage
Feed-water temperature chart

APPENDIX 2

MANUAL OF INSTRUCTION FOR BOILER FOREMEN

PART II. ECONOMY

When coal is fired in a boiler furnace, the heat goes one of four places:

1. Into the boiler.
2. Up the stack.
3. Into the ash-pit.
4. Into the air around the boiler setting.

Only the heat that goes into the boiler is used. The heat going the three other places is all wasted. The way to save coal is to reduce the waste. If you run the boilers in a way that will reduce the waste of heat up the stack, into the ash-pit and in the air, there is bound to be good boiler efficiency, which means saving

in coal. The main work that has to be done to keep down the waste of heat is explained below.

You should read over and study carefully what is explained, so that when some one comes to talk with you about it later, you can explain your side of it. That is, if there is any kind of work mentioned which cannot be carried out right in your boiler house, you will have to study over the reason why it cannot be done and tell this to the man who comes to talk to you about these instructions. It is very necessary that you understand fully all about what causes the waste of heat, and also that you understand that what may seem like a little thing, which does not do much harm, is often the cause of a big loss because it goes on all the time, day and night. A good boiler house foreman looks after the little things, before they get to be big ones, and this often saves a whole lot of trouble and also saves coal.

Inspection—After a boiler has been cleaned or repaired, you ought to inspect it carefully, outside and inside. It is a very good thing to have a union overall suit, with a hood on it, and drawstrings at the ends of the sleeves and legs. With this on you can go into any part of the setting without getting your clothes all spoiled.

If you let the boiler go without inspecting, or entrust the inspection to some one else, you will never know what shape it is in. The way to keep the boiler in good shape is to make this inspection work part of your job, which it is, and do it yourself. The men will soon see that whatever work they do in the way of cleaning outside and inside is inspected before the boiler goes on the line again, and it will make them more careful.

When you inspect a boiler, keep two points in your mind all the time: First, is there anything wrong which might affect the safety of the drums or tubes or headers or connections, etc. Second, is there anything wrong which may cause waste of heat—for instance, dirt on the tubes; holes in the baffles; scale in the tubes; mud in the drums; any brickwork in need of repairing, etc.

It is most necessary to look through the tubes when inspecting. If the tubes run from one drum to another, put a man in one drum with a light. You get in the other drum and have him move the light so that you can see through the tubes. If you use

an electric light in a boiler drum, be sure that the insulation on the electric wire is in good shape, or you might have a short circuit if a bare wire touched the steel of the boiler and some one get badly burned. If the boiler is of a different kind and has tube caps on both ends of the tubes, be sure to take the caps off both ends of some tubes, scattered around in different places, and look through these tubes, with a light at the other end. A man looking through tubes to learn their condition should look from the lower end up, with a vertical boiler or a Stirling type, and look from the back end forward in a straight tube boiler; then he will be sure to see any dirt or scale if there is any.

After you inspect the boiler outside and inside, you ought to make a note of its condition in your Record Book. This book should be big enough to last two or three years, and should be kept where it will be safe. When you make a note of the inspection, put down the date and the number of the boiler, and anything which you saw that ought to be mentioned. If everything was all right, say so, but it is necessary that you write down something about the condition of the boiler and the setting, for your own information and also to use in case something should come up about the safety of the boiler. You cannot be too careful in making complete notes every time you examine a boiler.

Heat Loss up the Stack—Most of the heat is wasted up the stack, and by keeping down this waste, the biggest saving of coal is made. A number of different things causes waste of heat up the stack.

If there are holes in the baffles, some of the gas will go straight through to the stack, without giving up to the boiler all the heat which it should give up. This makes the temperature of the gas in the stack higher than it ought to be, and the way to prevent this is to keep the baffles tight. Sometimes when tubes are taken out, holes are knocked in the baffles and these ought to be fixed after the new tube is put in.

Another cause of heat waste up the stack is dust on the tubes. If the fire side of the tubes is not kept fairly free from dust, this dust will have the same effect as if the heating surface were covered with an asbestos sheet, which will keep part of the heat from passing into the boiler. The gas passes from the fire to the stack

very quickly, and there is no time for the heat to soak through the layer of dust, as it takes much longer for the heat to pass through the dust than to pass through the steel of the boiler.

Blowing the dust off the tubes by hand, is something that you will have to look after to see that it is done right. Generally, once in 12 hours will be often enough, but it ought not to be put off any longer than this. Even if the flue blowers do their work as well as they can, there will be some corners that they cannot reach right. For this reason, the tubes ought to be blown off, or swept off, every time the boiler is taken out of service, and this is one of the reasons why you should inspect, as explained above. Do not let them blow water into the setting when first starting to blow, but blow the steam into the air until the blowing pipe gets hot. Wet steam in the cooler parts of the setting helps to bake the dust on the tubes, so that it will not blow off. If the boiler is wide and you can blow in only one side, it is better to use a longer lance for the part of the boiler farthest away, and a short one for the near side. Also you may find that a curved lance will help to reach some parts of the setting. Do not be afraid to use your head, and scheme out some things which will help the men to do their work right.

Another case of waste up the stack is scale or mud inside the boiler, on the heating surface. This has the same effect as dust on the outside of the boiler in keeping the heat from passing from the hot gas into the water. It is easy enough to keep the drums clean with water-tube boilers, and if you do not let it go too long, the shells of fire-tube boilers can be kept clean. The tubes have to be looked after the most, especially in the hottest part of the boiler. It is not hard to keep tubes clean if the work is done regularly. Use a turbine cleaner, and be sure that the size of the cleaner is right for the size of the tube. If the cleaner is too small, it will push through and leave a coating of hard scale. This is the reason why you should inspect the inside of the tubes after they have been cleaned. Don't allow the men to go through the motions of cleaning tubes, without making sure that they cut out the stuff that is in the tubes. Always keep in mind that there is no excuse for any scale in the drums, and no excuse for even 1/8 inch of scale in the tubes, because with the good turbine cleaners

that are now made, the scale can be kept out of the tubes if the cleaners are used often enough, and the inside of the tubes inspected after the men are through cleaning.

One of the greatest causes of waste of heat up the stack, is air leakage. The air which causes the greatest loss is that which gets into the setting through cracks in the wall and around the door-frames, between the boiler and the brickwork, between headers, and around the flue-blowing doors. All the air that gets in this way does no good at all, as it has no chance to burn coal, but it takes some of the heat away from the hot gas and carries it to the stack, and in this way keeps this part of the heat from passing into the boiler. All kinds of cracks in the walls between the headers and around door-frames, etc., ought to be plugged up in such a way that they will stay tight, and not have to be fixed over every few days. Asbestos rope is good for this, but it ought to be driven in tight. The worst leaks to stop are often around flue-blowing doors, because these doors have to be opened so many times. It is a good thing to have a bucket of asbestos plaster mixed up, and when a door with any leakage at all is closed, plaster up the cracks.

Do not forget that any air that gets into the boiler setting, except through the fire, is causing a waste. Holes in the fire, or thin places in the back ends of stokers and chain-grates waste heat by letting in air. The fireman must be made to keep the grates covered evenly, to keep air from getting through which does not burn coal, but only carries away heat to the stack.

Still another source of loss of heat up the stack is due to putting too much water on coal. Dampening fine coal when it is used in some kinds of stokers and on chain-grates, is a good thing to do, but it is very easy to put on too much water. If you can see the water on the coal, or if you take a handful of fine coal and squeeze it and it balls up with the water running out, wetting your hand, there is too much water on; but if the handful of coal feels damp without making your hand wet, the chances are the water is about right. A little water is a good thing, but it is very easy to overdo it.

Heat Lost in the Ash-Pit—Do not fire the coal in big lumps, no matter what kind of grates you have. It is better in every way to break the big lumps, when the coal is hand-fired. If the coal is fired with stokers or chain-grates, it will be passed through a crusher before it comes to the stoker hoppers. The crusher ought to smash it up so that the big lumps will pass through a ring 1 or 1¼ inches in diameter. With chain-grates, if there are lumps even half as big as your fist, there will be coal wasted with the ashes, because these biggest lumps will not all burn out from the time they catch fire at the front end of the grates until ashes and all are dropped off at the back end into the ash-pit.

No matter what kind of grates you have, there will be some fine coal and coke dropped through the front part. With a chain-grate there is a pan which runs back part way, so that this can be scraped out and fired over again. You should do this same thing with a hand-fired grate or a sloping grate stoker. Have the firemen scrape out the good coal in the front of the ash-pit once in a while and throw it back into the furnace. Do not let the firemen start to clean fires with flat grates, with a lot of good coke lying in the front part of the ash-pits, because when they scrape out the clinkers, these will fall on this good coke and cover it so that it cannot be used again. Have the good coke scraped out and fired before starting to clean.

Once in a while you should look at the ashes as they are loaded in the ash-car or wheelbarrow to take them out, and if there seems to be much coke, find out what boilers it came from and watch the firemen that have charge of those boilers.

Keep an eye on the grate-bars. Sometimes bars burn off and leave holes, through which the fine coal falls into the ashes. Sometimes the openings in the bars or between the bars are too wide. In hand-fired grates these openings ought not to be more than ½ inch wide, and on stoker grates, it should be less than this. If the openings are greater than ½ inch, or ⅝ inch at the outside, for clinkering coal, get the patterns changed. The waste of coal in the ashes can be kept down very low by paying attention to these things.

Heat Lost in the Air Around the Boiler Setting and Pipes—Every metal part that has steam on one side and air on the other ought to be covered with a thick pipe covering. Do not be afraid to get the covering too thick on boiler heads, flanges, etc. It ought to be at least as thick as the covering on the pipes, or from 1½ to 2 inches. The higher the pressure the hotter the steam, and with high-pressure steam inside and cold air on the outside, plenty of covering is needed to keep in the heat. All the heat that escapes from pipes with dry steam in them, causes some steam to condense and makes the steam wet. The water in the steam not only does no good, but it does harm, besides wasting the heat which was taken up by the boiler. When any covering is put on, no matter where, see that the work is done in a way that makes it look nice and adds to the appearance of the boiler or piping.

Firing—In hand-firing do not let the fireman fire more than one door at a time, and do not let him put in more than three or four shovels of coal at once. A scoop shovel will hold from 15 to 20 pounds of coal, and over one-third of the coal is roasted out as a good gas a very short time after the coal is thrown on the fire. It takes a great deal of air to burn this gas that comes off the coal first and, if much coal is put on the furnace, not enough air will get through the bottom of the fire to burn the gas which is coming off. The result of this is that a good deal of this rich gas will pass to the stack without being burned at all, and this causes a great waste of coal. For this reason do not put on much coal at a time.

Do not have the fire too thick. Five to eight inches is thick enough. A thick fire wastes the good gas that is in the fresh coal, by keeping the air from getting through to burn the gas, and it also keeps the grate-bars too hot and burns them. With some kinds of coal a thick fire melts the ashes, so that a thin clinker runs over the top of the grate. Piling in coal and making a thick fire does not make the boiler steam fast. Only the coal that burns makes steam, and the coal will not burn fast if the air cannot get through the fire to burn it, or if clinker forms and stops up part of the air space.

Keep the fire even in thickness, except on chain-grates and mechanical stokers, where it ought to be allowed to thin out to-

ward the ash end. The fireman should, by all means, watch the fires and keep them from getting too thick, and keep any thin spots leveled over. A thin spot lets a lot of air through that does not do any good, because it has no chance to mix with the burning coal or gas.

Do not let the fireman use the slice-bar very much, except when getting ready to clean fires. Let the fires alone; keep them from getting too thick; do not put in too much coal at one time, and the coal will burn and make a hot fire without digging and poking at it all the time. Once in a while if the ash-pit gets dark, it is all right to slide the bar around on the surface of the grate and make the fine ashes, which lie right on top of the grates, fall through the openings. This lets more air through and makes the fire burn better, but do not let the fireman force down the end of the bar and turn any part of the fire up-side-down and mix the clinker with the good coal. This will cause nothing but trouble.

Be careful in cleaning fires. Try to burn out the clinker as much as possible before it is dropped in the ash-pit or pulled out the door. In cleaning flat grates, throw the good fire over to one side and bar up slightly the clinker that is left, and then close the furnace and run for a little while until the spots in the clinker commence to look dark; then pull out all the clinker on that side and throw over the good fire on the empty grates. Put several shovels of coal on the good fire, and burn the clinker on the other side down in the same way. Do not let the fireman try to clean a very hot furnace with a thick fire. It should be burned down as just explained, then the fireman can work better in front of the furnace and not much coal will be wasted.

If the coal is very dirty and commences to "pile up" in the furnace and the fire gets too thick, even with all the draft on, it ought to be loosened up underneath with a bar, without pushing the bar up through the fire; then burned down as soon as possible and cleaned. There is nothing gained by shoveling coal on top of a thick fire after the ash-pit has gotten very dark, but a great deal can be lost in this way.

Dampers—When you want the boiler to make less steam, partly close the damper. Never shut the ash-pit doors, as this is very bad in many ways. Do not let the men open the front doors

of a fire-tube boiler and allow the cold air to blow in on the hot tubes. This is bad for the boiler and is no way to slow down its steaming. Always use the dampers, and fix them so that they can be used easily and set any place you want them. Do not have a damper that can be set only two places—wide open or shut.

After the fires are cleaned, do not allow a big pile of ashes to lie in front of the ash-pit doors and keep the air from getting into the ash-pit. Also, the fireman should not allow coal that has fallen in the ash-pit to lie there and burn. All such things keep the air from getting up through the grate bars where it will do some good.

Number of Boilers in Operation—A very good way to waste heat, is to have more boilers on than what are needed for the load. In every boiler plant the boilers have a certain horse-power at which they make the most steam per pound of coal. With ordinary boilers this will run from 25 to 50 per cent. over the rating, but you can get this very closely from the proper persons. From the number of boilers on, and the pointer and also the curve on the feed-water meter, you can see just what horse-power each boiler is averaging. From this you can judge whether there are too many boilers on. Do not have "loafing" boilers on the line, as this only wastes coal, and it wastes a great deal of coal too. It is much better to have one or two boilers banked, doing nothing, and the rest carrying the load running at the right capacity, than it is to have them all running and each one with a lower load than it ought to carry for best economy.

On Saturday nights and Sundays the load is altogether different, and a good deal of coal will be wasted at this time if too many boilers are kept on. After a man has been in charge of a boiler house for some time, he can easily learn from the meter about what the Saturday night and Sunday load will be. The boilers which carry this ought to run in the same way as they do through the week. It is altogether wrong to have more boilers on for this idle load than are really needed, and let them loaf along at any horse-power. A little study of the Saturday night and Sunday load will make it possible to run at good economy, summer or winter. The main thing to keep in mind is, that boilers

running at one-half or two-thirds of their rating may waste more coal than when they are being forced too hard.

Other Heat Losses—There are a number of other ways in which heat is wasted in a boiler house. All the steam which blows out of safety-valves is wasted. When the load is heavy and the boilers are working hard, and then the load suddenly drops off, the safety-valves will blow. All the steam lost out of the safety-valves means wasted coal. Some blowing is necessary at times for safety, but there is no need for blowing a long time. This is where easy handling of the dampers comes in right. If the fireman will partly close the dampers and slow down the feed of the coal, the blowing will soon stop. Of course you must know the load conditions so that the fires do not cool down too much, and are then not right to take up the load when it comes on. You have to use common-sense in this, as well as many other things in operating boilers, as to just how much to slow down. You can often judge from the way the mill is rolling and the time of day the stops come. There is no use in safety-valves blowing hard for a half hour or an hour right along.

All leakage of hot water from blow-off valves is a waste of coal. Generally two blow-off valves are put on for safety reasons, but both of these can be used for economy reasons as well. Of course there is a waste that cannot be helped when boilers are blown down, but any leakage at the blow-off valves when they are closed means that they ought to be fixed as soon as it can possibly be done.

Most feed-water heaters have recording thermometers. You ought to keep an eye on the chart which shows the water temperature. This temperature ought to be 200 degrees or over. Every 10 degrees that the feed water is heated means a saving of about one per cent. of the coal, so that if there is an average temperature of 150 degrees in place of 200 degrees, it means that five per cent. of all the coal used is taken to do the heating which ought to be done in the feed-water heater. The feed-water heater also helps out the boilers, as when the boilers are getting hot water they will make more steam in an hour than when they are getting cold water. For all these reasons, do not be satisfied with a feed-water temperature that is under 200 degrees. Of course you may go up

as high as 208 or 210 degrees, as the water boils at about 212, and it cannot be heated above the boiling point. It is not a good thing to boil the water in the heater, because sometimes the pumps give trouble and there is nothing gained by it.

Do not forget about steam leaks, as all the steam that leaks out is wasted. Also, when steam leaks at one place for a good while, it will cut the metal and make the joint or stem harder to keep tight afterwards.

General—In carrying out some things that have been explained above, you will need help from outside your boiler house. Do not be afraid to take up these things with your boss, and if taking them up one time does not do any good, take them up again—only be sure you are right. If you make an honest push to get things right, you will be backed up in what you are trying to do. Do not be satisfied to be boss of the boiler house, but be the engineer of the boiler plant. Your work has several different sides to it—you have to look after the safety of lives and property first; you also have to keep up steam pressure so that the boilers will supply the steam needed, but it is also part of your job to look after economy. In looking after safety and keeping up the steam pressure, do not forget about the economy.

DISCUSSION

Mr. Palmer Collins:* I am particularly glad to discuss this paper both on account of the fact that the point of view from which it is written is so new in the literature of the subject and also that I was with the author through a large part of the experiences he mentions and for many years his experience was practically my own. From the time in 1889, when, at his suggestion, there was kept the first record of the use of coal that had ever been attempted in the steel company where we were, to the time when the use of coal in all departments and for all purposes was so closely scrutinized that it was practically impossible for any to be used for a purpose which was not definitely known. At the

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time of which I speak all the steel company knew was that so much coal was paid for. The company did not always know how much was received, and sometimes did not get what was paid for.

There is not time for me to present any very well prepared discussion of this paper but I am glad to make a few remarks corroborating the statements of the author along the lines of safety, the necessity of attention to all details of design, and the training of the personnel of the boiler house, in an effort to maintain conditions as we know they should be.

Safety—All the author says in regard to the necessity for proper walks and platforms in order to make it convenient to get at all valves, is certainly of great importance. Bad conditions in this respect I have found recently even in boiler houses which have not been in operation for a great many years and a recent experience very well illustrates the matter from two different standpoints. In a boiler plant which has been in operation only six or seven years, all of the fittings on the connection between the boilers and the main steam line were screw fittings. One of these suddenly let go and the whole connection went through the roof, and in some way the valve wheel at the main line became connected with an electric wire. When the boiler foreman, of necessity standing on the steam-pipe, attempted to shut the valve he received a shock causing him to fall, escaping a serious injury only by good fortune. I would not suppose that a boiler plant erected as recently as this would have been equipped with screw fittings throughout. I would certainly recommend that such fittings be eliminated from this service.

Details of Design—It is certainly of the utmost importance to pay very close attention to the details of design of boilers and settings. This applies not only to large details but to small ones as well. Some of the most aggravating and wasteful troubles I have had to contend with in the past few years seem to be due entirely to the fact that the boilers of which I had taken charge were erected by the boiler manufacturers with their standard settings and no attention had been paid to the particular service in which the boilers were to be used. For instance, two boilers had been erected at the same time by the same company, one to be

fired with blast-furnace gas and the other with coal, and no difference in the settings had been provided to take care of these different conditions. The result was that the blast-furnace boiler with only one cubic foot of furnace volume per rated horse-power and three square feet of damper area per 100 horse-power would not develop their rated capacity although the draft at the base of the stack should have been sufficient. At considerable expense the settings were changed to give two cubic feet of furnace volume per horse-power and six square feet of damper area per 100 horse-power. This increased the capacity of the boilers to about 150 per cent. of their rating, without any other changes being made.

Another detail of design which I have found to cause a considerable amount of trouble, especially in waste-heat boilers, is the placing of steel columns and other structural work in the boiler settings. This is a prolific source of excess air and one which is very difficult to deal with, as the brickwork inevitably separates from the steelwork and allows the air to pass through. Although it may not be possible for air to leak through a solid brick wall, I have known the above condition to be taken care of, with a fair degree of success, by some of the numerous plastic cements which are on the market.

Training of the Men—This is about the most important subject in connection with boiler plants and it cannot, like design, be forgotten when the plant is erected, but starts at that time and must be continued. The reading of technical papers on this subject of boilers almost always leaves me with the idea that it would be very fine if the conditions described could be fulfilled and maintained; and the maintaining of good conditions in the boiler house by the education of the men directly in charge has been one of my principal efforts during almost 20 years' experience with boilers.

It is necessary not only that the man in charge of the boilers should know what should be done, but that he should be taught to have enough interest and enthusiasm to do what he knows should be done, and this is not always a simple matter.

The use of a manual of instructions, as suggested by the author, is very interesting, but I never personally tried such a

thing. I have depended more on getting into personal touch with the man in charge of the boilers in an effort not only to instruct him but to arouse his interest in his work. About the first thing along this line that can be done is to see that everything is made as convenient as possible. I have seen soot blowers which were an absolute failure, because they were installed in such a way that it was inconvenient to get at the chains to operate them, and which were later made quite successful by being made a little more convenient.

The next step should be to educate the man or men in charge and in this I should think the manual of instructions would be a very great help. The next step is to arouse the man's interest and with many men this naturally comes with a little knowledge which they could gain either by the manual of instructions or by personal contact. The incentive of competition is one of the biggest helps I have ever found. For instance, at one plant there were two boiler houses enough alike to be compared and in each boiler house a blackboard was installed on which was posted each month the overall efficiency and the horse-power per boiler of each boiler house. This very soon aroused a great interest in the men in each of the boiler houses. It was not long before they were making suggestions which resulted in quite an improvement in both capacity and efficiency. One of these was the installation of herringbone grate-bars as described by the author in place of the old style straight grate-bars although this same change had been previously opposed before sufficient interest had been aroused. Another result was the great reduction in the use of the slice-bar which is rarely needed in the low volatile bituminous coals used in the eastern parts of the country.

I am in hearty accord with the author's statements in regard to instruments in boiler houses such as are usually found about steel-works, and even without a CO_2 recorder I have gotten good results in the training of the men by a periodical use of the Orsat apparatus.

Wetting Coal—There are many kinds of coal which are greatly benefited by being burned wet on the chain-grate, and I agree with the author in what he says in this respect, that a con-

siderable increase in capacity can be obtained without any bad effect on the efficiency by wetting the coal. However, I have seen many times that coal such as Pittsburgh "slack" can be so wet that it seems soaked without actually containing more than eight or nine per cent. moisture.

Coal Analysis—The analyses of coal are used in many different ways and in one plant we even went so far as to try to grade the coal by analysis. My personal experience is that all such attempts are failures and that the best way to handle the coal supply in the steel-mill is to know what mines the coal comes from and to know what can be expected by good mining operations from these mines, and to use the average analysis of coal to see that the mining operations are kept up to a required standard. On many occasions I have known this effort to meet with very great success and, keeping in close touch with the man in charge of mining operations, I have many times been thanked by him for information in regard to the quality of coal being received from his mine.

I have been in close touch with the boiler situation in steel-mills for the past 20 years and I can very well understand the author's remarks in regard to criticism, as I have experienced it to a considerable extent. Steel-mill boiler plants frequently present bad looking conditions even where the actual results being obtained are not so bad, and this is frequently due to the fact that the company is in the business of making steel and not power and the mechanical departments are frequently so taken up with work in the mills that it is extremely difficult to maintain all conditions as they should be in the boiler plants. In regard to smoke abatement, my personal experience in these boiler plants is that the presence of smoke is not an indication of bad efficiency but that frequently the entire absence of smoke indicates a greater loss than you would be liable to get by the presence of it, and that efficiency must be maintained along with the abatement of smoke and not by it.

I wish to express here my appreciation of the value of the paper by Mr. Snyder and the belief that many of the suggestions in it can be used to good advantage in the work which I am doing.

MR. JOHN A. HUNTER:* When Mr. Snyder prepared this paper, I think he must have had in mind covering every detail of the equipment and operation of boiler plants so thoroughly that there would not be anything left to be said on the subject; and in so far as these features are concerned, he has succeeded admirably.

The paper is a very excellent presentation of the proper equipment for industrial boiler plants, and the appendix attached is a very good guide for the boiler-house superintendent. However, I do not believe that he has placed enough emphasis on methods of getting and maintaining the interest of the firemen; for when all is said and done, if the firemen are not interested in obtaining good results, good boiler efficiency will not be obtained, no matter what equipment is supplied.

I believe that too little emphasis has been placed on this fact in the operation of boilers in the past, and that if we wish to keep abreast of the times and increase the efficiency of our boiler plants, the biggest opportunities are through increasing the interest and efficiency of the boiler-house organization.

A great many of us do not realize the value of the fuel which is burned under the supervision of the fireman on one turn of 12 hours. Taking a modern sized boiler plant equipped with stokers, one fireman should supervise the operation of three 500 horsepower boilers. With coal at $3 a ton, these boilers will consume about $150 worth of coal per turn of 12 hours. This, I believe, immediately fixes the importance of doing everything to increase the efficiency of the firemen.

As pointed out by Mr. Snyder, the principal losses in the operation of boiler plants are: Up the stack, into the ash-pit, and into the air around the boiler setting. There are other losses, of course, but for any given coal they are fixed. The only losses over which the fireman has any control are the losses due to excessive air, and incomplete combustion as shown by the analysis of the flue-gas, temperatures in the flue-gas, and the combustible in the ashes. These losses are under the direct control of the fireman, and the difference between fairly good practice and fairly poor practice can easily amount to 10 per cent.

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On the basis as illustrated, the fireman can then either waste or save $15 per turn, which for a year's operation would mean $4500 for each fireman, or $9000 for the three boilers per year. Now in order to make this saving, it seems to me that we can well afford to spend considerable time and energy to educate the fireman and get him interested in obtaining better results.

In order to do this, the first thing is to obtain the good will of the fireman, and to make him feel that in trying to get him to produce better results, we are interested not only in the saving which can be made, but also in his welfare, in that we are teaching him to become a better fireman and giving him an opportunity to prepare himself to take a better position.

That he shall not be working in the dark, he should be furnished each day with a record of the results obtained on the boilers under his supervision and, as the three sources of losses over which he has any control can be shown by determination of the CO_2, stack temperatures, and combustible in the ashes, a record of these for each unit should be given to him.

In most industrial boiler plants, about the only time any one outside of the boiler house takes any interest in the fireman is when for some reason, in a great many cases entirely beyond his control, the steam pressure drops to such a point that the steam driven machinery can no longer be operated at its normal capacity. Then the firemen is "bawled out" for not keeping up steam pressure. So it has come to be that the fireman thinks that as long as he maintains a fairly uniform steam pressure he is performing his work very satisfactorily. It is of course essential that uniform steam pressure should be maintained, but this can be done and at the same time economic operation maintained.

To keep the records I have recommended will involve some expense, but the possible savings are great enough to more than warrant the relatively small expense for equipment and the additional help required to carry out this plan.

MR. J. C. HOBBS:* The Society is indeed fortunate to have presented to it in this paper the results of such a very long experience with boilers. Many of our papers nowadays are so filled

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with integral signs and mathematical equations that little or no space is devoted to data obtained from actual experience; with the result that the information is either in such a form that it is impractical to apply, or that it must be greatly modified before it can be used in connection with the daily problems encountered by engineers.

There is no part of this paper which I wish to criticize, because I heartily agree with Mr. Snyder. It may not be amiss, however, to emphasize two of the principal points which I believe Mr. Snyder has presented; both of which pertain, not to the mechanical details of boiler, furnace or piping construction, but rather to subjects of even more importance—the working conditions and the personnel of the boiler-room force.

Summing up, and putting it into a very brief statement, all I will say is that every reasonable, or in many cases special, effort is justified in providing the best working conditions for the boiler house operators—including stairways; platforms; railings; safety appliances of all kinds; clean, well-ventilated wash-rooms; and control equipment which will reduce to a minimum the amount of physical effort required to obtain results.

I believe Mr Snyder is right when he says that in new boiler installations the boilers should be increased in size; but, instead of stopping at 800 or 1000 horse-power units, I believe that where the steam demand is great the size should be 1500, 2000, or even 2500 horse-power because, as a practical operating proposition, it then becomes possible to engage men of the very highest class to control the combustion and other boiler operating conditions.

As long as ignorant firemen (many of them hardly able to speak the English language) must be employed, and where large numbers of firemen are necessary to handle a large number of small boilers, it is impossible to obtain enough of the right kind of men; and if they were obtainable the payroll would be so large we could not afford to keep them. There is no reason why boiler rooms should not be so designed that the working conditions would compare very favorably with those of any other kind of manufacturing employment. In fact, I have seen boiler rooms which were very much cleaner, and which I believe were operated

by men of higher intelligence, than are to be found in some of the machinery occupations where the conditions are ordinarily supposed to be vastly superior to boiler room conditions—and unfortunately, as a rule, they *are*.

That is the reason why men of the better class are hard to obtain and to keep in the ordinary boiler-room.

Bigger boilers, better boiler room conditions, and better boiler operators will go a long way toward reducing the cost of producing steam.

MR. A. L. HOERR:* There is one point in connection with the operation of industrial power-plants that is in danger of being overlooked in placing so much emphasis on the matter of efficiency and economy of operation.

When you are furnishing steam, the very first thing you must do is to furnish steam. It is a matter of no importance how much that steam costs, within very considerable limits. If you have a string of mills or blast-furnaces on a steam line you must have steam and steam is the first consideration. The steam must be supplied by some means or other.

The second consideration would be that that steam must be synchronized, so to speak, with the demand. It is not wise or desirable simply to make a lot of steam all the time. If the demand falls off, due to varying operation, your operation should be such that the steam supply falls off about in accordance with it. And after that has been done, it is time to begin on economizing. Your manager will not be at all interested in economy, if the steam you produce is the cheapest ever known, if you have at the same time two or three hours shut down of blast-furnaces because there is no steam.

Regarding Mr. Snyder's statement about the old-style boiler houses where the men knew nothing as to economy but simply knew about keeping up steam—he probably knows very well why that was, as do many of us who were in such plants. We had inadequate equipment. In many cases the boilers and engines and everything else were relics of the old iron-making mills and the mills had been enlarged, open-hearth furnaces were added and we

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began to roll steel. We did not have any new boiler houses or engines; we simply went on with what was on hand and the only thing we did was to try to make steam. It did not matter whether it was wet or dry, if we had enough pressure behind it to turn those engines over and produce tonnage. It is only in later years, as equipment became more suited to the work it was doing, that breakdowns and delays became so far apart that we had time to sit down and figure out ways and means of making the steam more cheaply.

In modern steam plants in steel-works and furnaces they will go away beyond the standards suggested by Mr. Snyder. We are using boilers of 1000 and 1500 horse-power capacity with 250 pounds pressure or more and a considerable degree of superheat. In fact some plants of that sort are now operated and others are being built.

But I always like to emphasize, first get your steam and after you are perfectly sure you have plenty of steam, see if you can make it more cheaply.

Mr. W. E. Moore:* This is a most interesting paper and practical men will appreciate it. Judging from the excessive temperature of this hall to-night, it would appear that the firemen in this building, in some way, have already seen and profited by the paper.

For some years I have been interested in pulverized fuel as a means for eliminating many of the troubles recounted by Mr. Snyder in the operation of boiler plants. I have recently inspected a very interesting installation of pulverized fuel under four 500-horse-power Babcock & Wilcox boilers at the Oneida Street Station of the public service company at Milwaukee. The boilers in that plant are being operated up to 270 per cent. of rating and with efficiencies up to 83 per cent.—an average efficiency about 20 per cent. higher than the boiler efficiencies mentioned by Mr. Snyder in his paper. The furnace is smokeless and the weight of ash handled amounts to only about 10 per cent. of the weight under other boilers in the same plant, fitted with modern underfeed stokers. The other 90 per cent. of the ash apparently is

*President, W. E. Moore & Co., Pittsburgh.

burned or volatilized and goes off unnoticeably with the waste furnace gases.

This installation was put in by the Locomotive Pulverized Fuel Company, represented by Mr. Dalley, who is here to-night and who might be able to give some further details of interest.

Mr. A. H. Charles Dalley:* Mr Snyder's paper is of interest to me because his viewpoint is practical. Visualizing boiler operation during a period of 20 years creates a great storehouse of practical ideas, and the paper I have had the pleasure of hearing this evening exemplifies, to a very high degree, an intelligent interpretation of the conditions, and practical plans for solving the many problems of reducing the waste of heat.

Mr. Moore, in his discussion, has very kindly referred to the installation of the "Lopulco" pulverized fuel system in the Oneida Street plant of The Milwaukee Electric-Railway & Light Company, Milwaukee.

A little less than a year ago, in May 1918, an installation of powdered coal equipment was made in this plant under an Edgemoor water-tube boiler containing 4685 square feet of heating surface. There are five of these boilers in the south end of the Oneida Street plant, which were installed over 20 years ago and operated with chain-grates and Jones stokers, and which are now equipped with the "Lopulco" system of pulverized coal.

The test to determine the efficiency at which the plant could be operated was run for a period of 24 hours. The boiler was operated at 117 per cent. rating, the coal used was Illinois and Indiana screenings, 10 779 B.t.u., as received, with an ash content of 14 per cent. The combined boiler and furnace efficiency obtained was 85.22 per cent.

As the drying and pulverizing plant was installed for the operation of five boilers of this size, and it was necessary to run the dryer and pulverizer intermittently for the operation of one boiler, the expense for operating—namely, 4.22 per cent.—can be reduced materially when spread over the operation of the five boilers; in fact, it is my candid opinion that the expense per ton for crushing, drying, puverizing and burning powdered coal with

*Locomotive Pulverized Fuel Co., New York.

the "Lopulco" system, in plants burning 50 or more tons of coal per day, is no greater than the cost of operating forced draft stokers and the necessary equipment for these stokers.

We have had to meet many problems in connection with the burning of pulverized coal, but I am glad to tell you that we have solved them all satisfactorily. The brick and slag troubles, which have been a close companion of pulverized coal up to the last year or two, have been corrected by us. We are now burning in our various plants, all kinds of coal, ranging from anthracite to lignite, without destructive effect on the brickwork and also without making slag. The refractory difficulty is avoided through a combination of simple parts and their operation. The proper control of the auxiliary air, the burner and feeder system, and a careful regulation of the stack draft, have enabled us to bring about the mixing and feeding of the fuel and air in our mixing oven furnace, in a manner that will control the flameway and permit perfect combustion and high temperatures without undue strain on the brickwork.

Most of the furnaces we have in operation are using very little more than 0.01 inch draft in the furnace, and this is practically balanced between the furnace and the first gas pass. Some of you have heard of installations where the combustion was of such a nature that the slag ran down the furnace ways and gradually eroded the brick.

In our experiments, carried over a period of a number of years, we have met and overcome these difficulties, and to-day are operating at very high capacities without any slag, and our ash difficulties have been reduced to a minimum. Only a small percentage of the ash is to be found at the base of the furnace. The greater part of it seems to disappear in the atmosphere.

It is the opinion of practical furnace brick masons, repairing walls for different types of stokers, where the "Lopulco" system is in service, that the brickwork in our furnaces will last from three to five years.

Mr. A. C. Myers:* As a brief and abrupt introduction and conclusion to my review of Mr. Snyder's paper, I can very

*Engineer, Cambria Steel Co., Johnstown, Pa.

sincerely and honestly say that I most heartily agree with every phase of the matter as he presents it, not due to the fact that it sounds good, but rather because it actually is, and has been proven to be, good. He has covered the ground so completely and explicitly that there remains really nothing new of importance to be added, consequently there is left nothing for me but to single out some favorite feature or features and add my emphasis to them.

To be pointed in my remarks and at the same time general in their application, I do think it is a very lamentable fact that such advice and experience has had and is still having such a desperate and difficult task in becoming recognized in its truly merited sense.

How reluctantly absorbed, carelessly handled, and willfully neglected has been this better knowledge of boiler room demands; not alone by the boiler room itself, but by the superiors in command.

Probably the boiler has been and is really "too modest," and being so, keeps too many of its abuses to itself; performs in a very creditable manner, whether housed or exposed to the weather, and makes steam whether attended by cheap labor or experts. But, be this so or not, it is not fooling itself very much, it is just as immovable as the most contrary manager in the office; it is making steam and otherwise behaving just in proportion to the amount of attention and the nature of the conditions surrounding it.

Probably some of us in reading Mr. Snyder's paper will be surprised at the numerous details there are in connection with boiler room practice, and it is well for us to stop and think a little as to whether or not we belittle a wonderfully large item, when we so carelessly say "What's the use" to many of the questions and criticisms directed at us, concerning this and that defect in our plants.

These many phases and features pointed out by Mr. Snyder are surely there, actually imposed upon us by the nature of the operations, and if we are knowingly not taking care of them, they are taking care of themselves and never, for very long, toward any other end than plant detriment and high costs. The point that "it is of no use for engineers and boiler manufacturers to

give attention to . . . details, unless, corresponding attention is given to . . . . daily service," is very well taken.

It is the height of folly to be so discriminating and critical in making up the specifications to cover every studied point of operation, and to provide for everything, and then turn the entire installation "loose among itself." Modern equipment and facilities for efficiency do not relieve the boiler room force from being observing and attentive, but they do increase vastly the scope of observation, locate in minimum time the source of trouble, harmonize every feature, and tend toward making what we used to call a test or nursed result, the maintained result week in and week out.

Relief from worry and confusion, is a long step toward efficiency in any walk of life, but such relief must not degenerate into carelessness or into indifference; consequently while matters have been unquestionably improved by the proper application of modern boiler room methods, both for the manufacturer and for the employee, there still remains the personal element in man with which we must deal and which we must improve.

It may be perfectly correct to place strictly labor saving devices in the hands of illiterate and untutored men; but only such devices as are to operate in unison with some other operation, and where the eye alone is really the brain. Only such devices and their class of service can be so treated, and the result must be looked for directly in capacity, the economy of the feature following indirectly. But, where we have to deal with wastes in order to effect economies, we truely have a mental problem back of which no agency in this wide world, save education in the principles of the operations involved, will correctly serve the purpose. All the advantages of boiler room equipment as previously exploited will never measure up to their capabilities, if the men in charge are nothing more than automatic regulators with no realization whatever of their responsibilities and of the real purposes of their equipment.

I use the word realization unreservedly, in preference to the word knowledge, because the most illiterate laborer, by working a sufficient length of time around much of the equipment, may acquire knowledge enough concerning this equipment to repair

it and keep much of it in good order, but the benefit will more than likely be reflected only in the condition of the machine and not in the costs or economies of the department. Consequently, I have nothing but commendation for Mr. Snyder's systematic plan of education for the boiler room force—and that to the limit of their capacity.

The plan may not produce the results for which we are looking, within the expected time—due in a great measure to the large foreign element employed—but undoubtedly the technical man periodically engaged in preparing plans or in conversational instruction will absorb from his own plant facts and realizations which never before had entered his head.

This being true, and my own experience bears out the statement, the matter works for the good of both the technical man and the workman. Finally, if we are justified in installing high-class equipment to effect the savings we deem necessary, we must have a better class of operators; the equipment we can purchase, but the men we or some other plant must develop, and if some one else develops them we will soon have to buy them too.

But with the advance in mechanisms and equipment, we make a sad mistake if we consider that we can let the personal element remain at a standstill and the machines do it all.

Labor-saving machines, fool proof machines, and automatic machines are quite the thing whenever and wherever they can be installed but, as I have already stated, where economy and efficiency depend almost entirely on the reduction of wastes, as they do in boiler room operation, all such forms of mechanisms are limited in their regulation, and just so far as they fall short man must make up the deficiency. He is the final balancing and regulating unit and must be trained to co-operate and act as such. He should be considered as the final refinement and not as an original or crude improvement.

Author's Closure: I am sure that I appreciate very much the words of commendation which have been spoken by the various men discussing this paper. There seems to be a very general agreement in the discussions that the methods suggested in the paper are advisable and will prove beneficial. While I have not developed these as completely as I hope to within the next

two or three years, we have gone far enough to know that there is nothing suggested but what is practicable, and when these methods have been used in certain boiler plants, the results have been surprisingly good. I have not taken the time and space to submit evidence on this point, but I have made a number of comparisons between plants where the principal difference was in the superior knowledge and skill of the operating crew in the one plant, as compared to the other. All these comparisons show a very substantial saving in fuel, which results from improving the efficiency of the men.

To one who had not given much study to the matter, the suggestion of an instruction book for boiler house foremen, and even for firemen, might seem rather impracticable, but it is not so in any sense of the word. Instruction courses are now given by many large manufacturing companies, to salesmen, foremen and other employees, with the object of better fitting the men for the work which they have to do. This does not necessarily mean getting more work out of the men in a given period of time, but it means helping the men to do their work in such a way that it will be easier for the workers, and the results better for the employer. This matter of an instruction book for boiler house foremen and firemen is simply an extension of this general subject of better training of employees, in a department where better training is badly needed.

The discussion of Messrs. Moore and Dalley in regard to pulverized coal for boilers, is interesting, and may indicate a new method of using coal under boilers which will do much to increase the efficiency. Of course I know that pulverized coal has at times in the past been used under boilers, but there have always been difficulties of one form or another to overcome, so that its use never extended very far. In this paper, however, I have tried to confine the main part of the discussion to dealing with existing plants and tried not to deal with special types of boilers or combustion apparatus. To include such subjects would have necessitated making the paper too long to serve the purpose which this one must serve. It is to be hoped, however, that we may have a paper in the not distant future which will cover in detail this matter of the use of pulverized coal under boilers, bringing it up to date.

SOME CONSIDERATIONS WITH REGARD TO FUEL GAS

By Fred. Crabtree*

Generation and application of heat play an indispensable part in almost all industrial processes and the success of these processes is largely dependent upon the economy and efficiency with which heat can be produced; thus an adequate and satisfactory supply of fuel is still one of the most important assets that any industrial community may have.

New ideas and improvements in the utilization of fuel are constantly being developed. Industrial changes, engineering progress and the production of new, more elaborate or more specialized products, continually create new problems in the application of heat; so there is always room for the discussion of some phases of the fuel question. Often these discussions bring out nothing really new; they simply help to make known more generally facts that had been known to only a few men; but as these facts can be of value only when utilized, and the more widely they are known the more generally they are likely to be utilized, such discussions have a real value. This is the only excuse to be offered for the following observations on certain phases of the fuel gas situation.

More than a year ago my attention was called to the problem confronting a local manufacturing company which had long depended on natural gas, but recognized that it would be only a short time before the supply would become unavailable, or so uncertain as to make some other fuel necessary. The company had a number of furnaces on the upper floors of a many storied building, half of the furnaces being at each end. They had been consuming more than 500 000 cubic feet of gas per day, and they desired a substitute which could be used in the same furnaces with the least possible change and which could be brought to the fur-

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naces conveniently and at a cost not too far above that of natural gas. Failing that, it would be necessary to reconstruct the plant.

This is the situation that confronts many manufacturing concerns to-day, and makes us realize, as we never did before, the great advantages we have had during the past few decades in natural gas. We have long theoretically recognized the convenience of gaseous fuel, particularly for small furnaces; but we have not fully grasped the unique qualities of the great gift preserved for us in the earth's storage places through many thousands of years, only to be frittered away in half a dozen decades. A stable, fixed gas, only slightly affected by ordinary changes in temperature; free from dust, tar, or injurious solids; of high calorific power, permitting of the attainment of high temperatures without preheating, and of the use of small mains; free from sulphur and not actively poisonous; and obtainable at such low cost. What these mean becomes apparent when we try to provide a substitute.

Of course for certain types of large furnaces, such as openhearth furnaces, soaking-pits, etc., the ordinary uncleaned producer gas serves very well and is inexpensive; but its low calorific power and large content of soot and tar impose restrictive limitations. It is not conveniently distributed to a large number of small furnaces; where comparatively small valves and close regulation are desired the tar and soot may cause trouble or annoyance—and it is along just these lines that the growing refinements in nearly all branches of industry are creating ever increasing demands. The constant tendency is toward a closer control of temperature and a more delicate adjustment of conditions in the furnace, both as to uniformity of temperature in some cases, and of the location of the point of maximum temperature in others. Only comparatively recently has the significance of these factors received the attention it deserved; and now we find that our greatest natural aid in securing these results is failing, just as we are learning to use it to best advantage.

It is true that for some of the larger types of furnaces, powdered coal is very well suited, and undoubtedly its uses will be extended; but for some time they will be as restricted as those for raw producer gas; but for a great many purposes, and for a large number of furnaces there will be wanted an artificial gas

that is stable and clean—i. e., free from tar, soot, or any other substance that will tend to settle in the mains or clog the valves.

As answering these conditions we have the following:

By-product coke-oven gas.
Bench gas (ordinary coal-gas).
Cleaned producer gas.
Water-gas (blue gas), carbureted or uncarbureted.

By-product oven gas has about half the heat value of natural gas, and is otherwise very satisfactory; but only a few large companies—usually steel companies operating blast-furnaces—care to make the large investment required for by-product ovens, and such companies need all the gas they produce. It is probable that in the future other companies may adopt the plan of the People's Gas Company, of Chicago, build by-product ovens, distribute the gas, and use the coke for making water-gas for domestic and commercial use.

Ordinary distilled coal-gas—technically called bench gas—is practically identical with by-product oven gas and equally satisfactory as to heating value and convenience; but its cost, unmixed with other gas, is prohibitive for manufacturing purposes.

Water-gas, frequently called blue gas, has a somewhat lower heat value than by-product gas (usually about 300 to 325 B.t.u. per cubic foot) and is stable and free from tar, soot, and other deleterious solids. For certain types of furnaces it is excellently adapted, and is, in fact, almost as satisfactory as natural gas. Its composition varies slightly, but a typical analysis is given as follows: CO, 43.5 per cent.; H_2, 47.3 per cent.; CH_4, 0.7 per cent.; CO_2, 3.5 per cent.; O_2, 0.6 per cent.; N_2, 4.4 per cent.

Being composed almost entirely of CO and hydrogen, its flame has comparatively low radiating power; hence it would not be satisfactory in open-hearth furnaces or other reverberatory furnaces depending on a flame with high radiation effect. But it is very satisfactory for furnaces depending on convection or conduction, especially those where close adjustment and regulation are desired—as, for example, furnaces of the surface combustion type, whose accuracy of control and high efficiency should lead to widely extended use. Having a comparatively high calorific in-

tensity, or flame temperature, it can be used in many furnaces without preheating, thus saving the cost of regenerative or recuperative chambers. It can, of course, be used equally satisfactorily where milder temperatures are desired.

The fuel required—either anthracite or coke—places some limitations upon the extended use of water-gas; but one or both of these can usually be obtained at a reasonable price at most of the leading industrial centers, and Pittsburgh is pretty well favored in this respect. To get the best results with coke, a good strong coke, equivalent to that required for iron blast-furnaces, is desired. It is not necessary that the coke be in large pieces; but owing to the evil effects of irregular distribution of the blast (channeling) a reasonable degree of uniformity in size is desirable. Experiments have been tried with a mixture of coke and bituminous coal, with the object of getting a richer gas, containing some illuminants. The idea is alluring; but, so far as could be learned, all these experiments gave unsatisfactory results and indicated that a straight coke charge is better than a mixed charge.

Water-gas has been extensively used for 30 years or more in the production of artificial illuminating gas in nearly every city of any considerable size; but for this purpose it has to be enriched, or carbureted, by means of oil, sprayed onto highly heated checker brick through which the water-gas is passing. The oil is broken up, forming fixed gases that mix with the water-gas, giving a resulting mixture that has a heat value of 600-650 B.t.u. to the cubic foot. This is one of the richest gases obtainable, but the high price of oil ordinarily makes the increase in heating value too expensive to be justified for industrial purposes.

Costs of construction are, of course, quite variable, in accordance with business conditions; and so are operating costs. So many of the factors involved vary with each individual plant that, without some knowledge of these factors, definite figures are apt to be misleading. But to the engineer and business man they are all important; so I venture to offer some estimates made in regard to one or two separate installations that were under consideration.

For a plant to furnish the equivalent in blue gas of 22 000 000 to 24 000 000 cubic feet of natural gas per month (800 000 cubic

feet per day), the installation cost early in 1917 was roughly estimated by the manufacturers of the equipment at $175 000 to $200 000, and the operating cost at 15 to 17 cents per thousand cubic feet—or the equivalent of 45 to 55 cents per thousand cubic feet of natural gas.

Quite recently there was made a very careful study of blue gas manufacture, and an estimate for a plant of about 40 times the capacity of the one above mentioned. Including some refinements or improvements in equipment and methods, the estimated installation cost was over three million dollars, and the estimated cost of the gas less than 8½ cents per thousand cubic feet.

This was for a gas of less than 300 B.t.u. per cubic foot, and the estimated cost of the equivalent of 1000 cubic feet of natural gas was less than 30 cents. In this case the coke was figured at less than $2.50 per ton; and the labor, repairs and maintenance were based on information furnished by the manufacturers of the equipment. The great size of the installation probably accounts for at least part of the decrease in estimated cost of the gas. However, it is the opinion of men engaged in the manufacture of blue gas on a large scale elsewhere, that actual experience would probably show a cost nearer 12–13 cents per thousand cubic feet, at least, or 38–42 cents for the equivalent of 1000 cubic feet of natural gas.

There are at present only a few plants making blue gas for industrial heating purposes. One visited was at the Hawthorne works of the Western Electric Company at Chicago. It was reported by the officials of that company to have given very satisfactory service.

The other possibility mentioned was ordinary producer gas, cooled and cleaned so as to be readily transported for moderate distances and to give little trouble from tar settling in the mains or clogging up the burners. During the past four or five years a great deal of attention has been paid to the question of cleaning producer gas, and some interesting results have been obtained. Many methods have been proposed, and some at least have given pretty good results. Among those suggested the following may be mentioned:

Filtering.
Precipitation by repeated contact with zigzag surfaces.
Rotary scrubber.
Electrical precipitation.

Several plants have been installed to use the filtering system —mostly by the Smith Gas Engineering Company's glass wool filter. Experience with the filtering system seems to indicate that its satisfactory working depends very largely on the way the producer is working. If the latter is at the right temperature, the nature of the tar produced is such as to give comparatively little trouble with the filter; but if the producer gets too hot, or channels too much, the tar becomes very sticky and quickly clogs the filter, causing either trouble with the flow of gas or excessive labor in cleaning the filters. Smith producers and gas cleaners have been installed at several works, including those of the Ford Motor Company, the Halcomb Steel Company, and the Erie Forge Company.

The zigzag-path precipitator, designed by Flinn and Dreffein, of Chicago, has been installed at a good-sized steel works in Ohio at a total cost, including producers, of about $125 000, the equipment being expected to gasify about 40 tons of coal a day, and clean the gas. However, it has never been put in operation, as the supply of other gas has been sufficient; but the chief engineer reports that he recommended it after seeing it in operation at a small plant in Illinois, and comparing it with several plants cleaning gas by the filter system. The one small plant using this system was getting quite satisfactory results.

The third system of cleaning mentioned was by a rotary washer. It was first mentioned to me by Mr. G. C. Lowell, formerly superintendent of the Gary by-product ovens. He stated that considerable experience in transporting by-product oven gas, by the aid of a booster fan, convinced him that a centrifugal blower was one of the most efficient instruments yet devised for removing tar from gas. Later, it was learned that the Pittsburgh Plate Glass Company had installed two plants of this type, only one of which, however, has been in operation as yet; but it has given excellent satisfaction as regards simplicity, reliability

and economy of operation, and effectiveness of cleaning. The installation consists of duplicate units throughout—producer, spray cooling tower, rotary scrubber, and booster fan. There is also after the scrubber a box containing excelsior, to act as a guard filter; but so little tar is left in the gas after leaving the scrubber that it is only at long intervals that the excelsior is changed. The plant in operation, using one unit, gasifies 20 tons of coal a day. The other plant, not yet operated, was calculated to gasify 40 tons of coal a day with half the units operating and half in reserve; or 75–80 tons a day with all units in service. Exclusive of producers, this equipment cost a little over $100 000.

An equipment of apparently this same type was used by the United States Bureau of Mines in its investigations of producer gas, and is described in United States Bureau of Mines Bulletin, No. 13, pp. 25–26.

The rotary scrubber built by the Buffalo Forge Company, in general principle resembles the Theisen washer, so long and successfully used in cleaning blast-furnace gas for gas-engine use. The Theisen washer in practice reduced the dust to 0.005 grain per cubic foot of gas. The rotary scrubber is guaranteed to reduce the tar in cleaned producer gas to 0.015 grain, or less, per cubic foot.

Accurate detailed costs of cleaning producer gas by either of these methods could not be obtained, but it was stated that when the cost of raw producer gas was equivalent to 12 cents per thousand cubic feet of natural gas, the corresponding amount of cleaned gas from the rotary scrubber cost 18 cents. This indicated that the cost of cleaning was about 0.86 cents per thousand cubic feet.

The remaining method of cleaning producer gas mentioned above is by electrical precipitation. Three variations of this method have been proposed. The original one, known as the Cottrell process, uses direct current with intermittent discharge. A modification by a Pittsburgh man, Mr. A. F. Nesbit, uses direct current with continuous discharge, and the process offered by the Steere Engineering Company uses alternating current. Of these three, it was possible to get data as to satisfactory operation from only one installation—that at the plant of the Minnesota Steel

Company at Duluth. It is of the Cottrell type, designed in detail by the steel company's engineers to take care of 5000 cubic feet of gas per minute, and its efficiency is indicated by the following results of a test extending over several days:

	Average	Maximum	Minimum
Raw gas, grains of dust and tar per cubic foot............	0.0876	0.2162	0.0347
Clean gas, grains of dust and tar per cubic foot............	0.0059	0.0110	0.0026

Measurements taken at 28.9 inches, barometer, and 40 degrees F.

The following quotations from a letter concerning the installation may be of interest:

"The high tension transformer has a rating of 200 volts to 30 000 and 70 000, at a 10 K.V.A. capacity. This unit runs at about two-thirds load all the time. The motor on the rectifier consumes about ½ H.P. current. The maximum current that we have ever used on the installation on both motor and transformer is 9 K.V.A.

"Barring the usual repairs required for electrical equipment, the apparatus requires practically no attention.

"We have had no trouble with insulation and this is probably due to the fact that the high tension insulators were installed with great care and provision was made to keep all moisture from the insulating mediums.

"Cleaning does not add materially to the cost of the gas, but whether it does or not, we find it an essential in the operation of our gas engines."

A Pittsburgh company experimented several months ago with an electrical precipitation plant, with somewhat encouraging results; but before it was perfected the war conditions made it necessary to suspend the experiments for a while. In this case the removal of tar was very satisfactory until the insulation broke down. When the insulation defects are overcome, it is expected that the apparatus will probably work continuously with good results, but until these are obtained the company will give no detailed information.

It is apparent, then, that the cleaning of producer gas is neither a difficult nor a very expensive process, and it can be accomplished by at least four different methods. The rotary

scrubber apparently does not remove quite as much of the tar as do the filter and electrical precipitation methods, but it is apparently simple and reliable, giving very little trouble in operation. The figures quoted would indicate that the electrical precipitation equipment, if properly designed and installed, will give a more perfect removal of the tar with perhaps equal reliability and simplicity of operation and perhaps at a lower cost.

The cost of raw producer gas, of course, varies greatly, mainly with varying prices of coal, but also with labor conditions and with the type of producer. Inquiries made more than a year ago showed that for conditions existing in 1916, at five typical steel plants, the costs of gasifying a ton of coal ranged from 45 to 61 cents with mechanically poked producers, and from 78 to 98 cents with hand poked producers. Costs of coal ranged from about $1.70 to $3.30 per ton, and the costs of gas from 1.6 to 3 cents per thousand cubic feet. Converting these figures to the equivalent of 1000 cubic feet of natural gas, we find them to range from 11 cents, with low priced coal and mechanically poked producers, to 22 cents with hand poking and the higher priced coal. This does not include interest and depreciation charges, amounting perhaps to 0.6 cent per thousand cubic feet of producer gas or 4.2 cents per thousand cubic feet of natural gas.

Recent figures seem to indicate that at the present prices for coal and for labor, the cost of the raw producer gas equivalent to 1000 cubic feet of natural gas, in this district, would be close to 25 cents. Cleaning by the above methods would probably add from 5 to 10 cents to this cost.

This analysis would indicate that water-gas is slightly more expensive than clean producer gas, if we take into account only the costs of production. On the other hand, the latter requires larger gas mains, a little more power to pump it any considerable distance and, for some of the higher temperatures, requires a more expensive installation in the form of checker chambers.

DISCUSSION

Mr. George L. Norris, *Chairman*:* I think we will all agree that even in this center of natural gas the development of a cheap and efficient artificial fuel gas for industrial purposes is very necessary. I think I saw one of the Smith Engineering Company producer-gas plants, mentioned by Professor Crabtree, in operation four or five years ago at the works of the Mitchell Motor Car Company at Racine, Wisconsin. The plant seemed to work quite satisfactorily using anthracite as a fuel. The principal trouble, as far as I could discover, was that there was practically no storage capacity and as a result they had to resort to fuel oil to help out during certain periods of the day. That error, of course, is one often committed on the score of economy of first cost, with the result that the installation of an extra furnace overloads the plant, or sometimes even makes it impossible to operate all the furnaces planned.

The paper is now open for discussion.

Mr. A. E. Blake:† I was unable to obtain an advance copy of the paper; so I prepared what I thought might be a suitable written discussion, but before going into the written discussion there are one or two points that might be brought out on the subject of surface combustion.

One thing mentioned was the advantage of luminosity of flame and how surface combustion could outweigh that. I think that it would be pretty hard to find a gas producing a luminous flame that did not contain carbon, and my understanding has always been that when you have a flame the combustion is comparatively so slow that the carbon has time to get into the elementary state and become temporarily luminous. If you burn your carbon before it gets into the elementary form—we do not

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†Surface Combustion Co., Pittsburgh.

know whether it gets into the elementary form or not, but anyhow you burn it before it has time to become luminous, and you shoot your products of combustion against some portion of your furnace and make that luminous—it does seem as though, in view of the results obtained, you do get your radiant energy just the same. Both the upper and under side of a flame produce radiant energy. That coming from the under side can do work in the furnace, but that produced on the upper side merely heats the arch. By devoting ourselves to making the arch incandescent and eliminating anything which may obscure the path from it to the work, we are able to obtain results which are surprising, to say the least.

Now flame temperature is a subject that is really not a subject. I do not know just what is meant by flame temperature, and I don't think anybody else does. It is possible to dip your hand in a fluid very easily prepared and hold it over a light until ignited, and you will get flame and your hand will not suffer any discomfort. Reaction temperature seems to me to be the most appropriate term to use, and then you do not have to bother about the flame.

Coming to the subject of producer gas, an interesting little installation with which we are familiar has been made using Smith producer gas, and in the particular system that is used, a booster with a water seal is employed to supply the gas at about one pound pressure. This water seal is found to scrub the gas sufficiently so that the inspirators we use will not be tarred up, and the proportions will be held fairly constant.

In coming to the Pittsburgh district to talk about burning gases I soon found, especially in connection with large projected plants, that blue water-gas is almost unknown. A good many inquired what the stuff was; but I think it is much better known now by those particular engineers.

The following gives the approximate cost of six 11-foot twin blue water-gas sets with daily capacity of 25 000 000 cubic feet (one set idle); also the cost of blue water-gas vs. producer gas per million B.t.u.

The estimate on the blue water-gas installation is based on prices of about September 1, 1918.

Your attention is particularly called to the advantages of the blue water-gas plant with central location, all materials being handled at one point, delivering a clean and practically dry gas of uniform quality at the condenser outlet. This gas can be delivered to any point with low distribution cost.

The producer-gas plant (bituminous coal), to insure clean product, will require the necessary scrubbing and preheating apparatus, and furnishing the same total heat as the blue water-gas plant would require installation of producers at various locations with necessary facilities for handling material at different points.

The producer-gas plant will need adequate steam plant for furnishing the required steam, with fuel storage and auxiliary apparatus for handling materials; whereas the blue-gas plant, with utilization of the waste-heat boilers, will supply 90 per cent. of the steam required.

APPROXIMATE ESTIMATE FOR BLUE-GAS PLANT, PITTSBURGH DISTRICT. SIX 11-FOOT TWIN SETS, WITH WASTE-HEAT BOILERS

Generators, castings, etc.:	
Twelve sets generators	$ 32 000
Twelve sets grates and hold-up bars	5 500
Combustion chambers:	
Six 10′ 6″ by 16′ 3″ combustion chambers and castings	10 000
Loose castings	500
Reverse steam connections	13 000
Valves	5 000
Linings	84 000
Hydraulic operation	18 000
Machinery:	
Four 35 000-ft., 40″-pressure, turbine blowers at $9000 erected	36 000
Blast mains	20 000
Scrubbers and seal pots	25 000
Take-off mains	10 000
Piping, 4 × $8000	32 000
Air and steam controls, 4 × $1500	6 000
Specials, 4 × $900	3 600
Operating floor, 16 000 sq. ft. at $2	32 000
Scrubber valves and connections	10 000

Miscellaneous:

Drawing	3 000
Inspection	1 000
Freight, etc.	6 000
Handling charges	1 500
Local material	2 900
Field engineering	6 000
Erection labor	9 000
Liability insurance	1 000
Final inspection	200
Operating expenses	2 500
Boiler makers' expense	3 000
Tracing material	1 500
Expediting	1 500
Premium on castings	15 000
	$396 700
Contingencies, 10%	39 670
	$436 370

Waste-heat boilers:

Six sets structural steel supports (not to exceed 40 000 pounds) 240 000 pounds at 8 cents	$ 19 200

Boilers:

Six 9′ 6″ boilers, 350 four-inch tubes, etc., at $12 000	72 000
Castings at $500 (no retarders)	3 000
Washers and castings at $2000	12 000
Steel connections, combustion chambers to boilers, 24 000 pounds at 8 cents	1 920
Stacks, platforms, connections and castings, 2 × 1.5 or 3 × $6865	20 595
Coverings, 3 × $1500	4 500
Linings, 3 × $3000	9 000
Soot blowers, 6 × $100	600
Feed-water heater and piping, 3000 horse-power heater	7 500
Pumps	1 500
Boiler fixtures	3 600

Miscellaneous:

Welding tubes	6 500
Bolts, nuts and washers	300
Local material	200
Drawing	2 500
Shop inspection	900
Freight and unloading	5 500
Handling charges. Shop	150
Erection labor	7 500
Field engineering expenses	2 000
Liability insurance and boiler policy	1 500
Boiler makers' expense	4 500
Expediting in shop	1 000
Tracing material	500
Premium on castings	3 500
	$191 965
Contingencies, 10%	19 197
	$211 162
One 1 000 000 cu. ft., 3-lift holder, 125′ diameter	110 000
Two pushers, 20 000 cu. ft., 30″ pressure at $15 000	30 000
Six 8′ 6″ by 22′ 0″ condensers, seal pots, connections, etc	48 000
Yard connections	15 000
	$850 532
Engineering fees and overhead, 15%	127 579
Total	$978 111

Interest, 6%	$59 130
Depreciation, 3%	29 565
	$88 695

Gas made (365 days) 9 125 000 000 at 0.97 cents per thousand feet or 0.97 cents × 3226 cu. ft. =.... 3.12 cents per million B.t.u.

Operating cost ....28.91 cents per million B.t.u.

Total cost ....32.03 cents per million B.t.u.

BLUE WATER-GAS PLANT (DAILY CAPACITY 5 000 000 CUBIC FEET PER SET) SIX 11-FOOT TWIN SETS (5 OPERATING)

Capacity of plant per day	25 000 000 cu. ft.
Gas made per ton fuel	54 000 cu. ft.
B.t.u. delivered per ton fuel (310 B.t.u. per cu. ft.)	16 740 000
Steam in addition to waste-heat boiler, per ton	540 lbs.

Cost Per Thousand Cubic Feet

	No. men	Shifts	Total men	Daily rate	Amt.	Total	Cost per 1000 cu. ft. in cents
Supervision:							
Superintendent	1			20	20		
Asst. "	1			10	10		
Night "	1			8	8	38.00	0.155
Boiler labor:							
(300 h-p.)	2	3	6	4	4	24.00	0.100
General house labor:							
Gas makers	5	3	15	5	75		
Helpers	5	3	15	4	60	303.00	1.211
Clinkers	12	3	36	4	144		
Screening ashes....	2	3	6	4	24		
General labor:							
Engineers	1	3	3	5	15		
Condensers, etc....	1	3	3	5	15	30.00	0.120
Mechanics:							
Machinist	1		1	6	6		
Blacksmith	1		1	6	6		
Fitter	1		1	6	6	30.00	0.120
Helpers	3		3	4	12		

Power water, etc.	0.100
Repairs to apparatus	1.200
Repairs to buildings	0.100
Boiler fuel, 10 lbs. steam per thousand cu. ft. at \$2.50 per ton coal....	0.156
Generator fuel, 38 lbs. per thousand cu. ft. at \$3.00 per ton coal........	5.700
	8.962

One thousand cu. ft. blue gas (310 000 B.t.u.) 3226 cu. ft. per million B.t.u.

$8.962 \times 3226 = 28.91$ cents per million B.t.u.

PRODUCER-GAS PLANT (24 TONS COAL PER PRODUCER)
(20 PRODUCERS, 18 OPERATING)

Capacity of plant per day..430 tons standard gas coal
Gas made per ton of fuel ....120 000 cu. ft.
B.t.u. delivered per ton of fuel...18 000 000
Steam required per ton of fuel..2540 lbs.

Cost Per Ton of Coal Gasified

	No. men	Shifts	Total men	Daily rate	Amt.	Total	Per ton gasified
Supervision:							
Superintendent	1		1	20	20		
Asst. "	1		1	10	10	38.00	0.090
Night "	1		1	8	8		
Boiler labor:							
(1000 h-p.)	4	3	12	4	48	48.00	0.112
Producer labor:							
Gas maker.............	4	3	12	5	60		
Helpers	6	3	18	4	72	180.00	0.419
Ash men	4	3	12	4	48		
Mechanics:							
Machinists	1		1	6	6		
Blacksmith	1		1	6	6	30.00	0.070
Fitters	1		1	6	6		
Helpers	3		3	4	12		
Power, water, etc.							0.058
Repairs to apparatus							0.480
Repairs to buildings							0.064
Boiler fuel, 2240 lbs. per ton at $2.50							0.380
Gas coal, 1 ton at $3.25							3.250
							4.923

One ton of coal (120 000 cu. ft., 150 B.t.u.) = 18 000 000 B.t.u.
4.923 ÷ 18 = 27.35 cents per million B.t.u.

It will be seen from the foregoing, that the cost per million B.t.u. by the use of water-gas is 1.56 cents more than the cost per million B.t.u. by the use of producer gas. When one considers the great difference in the two fuels by reason of the great dilution of producer gas by what may be termed deadwood in the form of the nitrogen, which cannot be avoided in the gasification of coal in the formation of producer gas, it will readily be understood that the small added cost of the blue water-gas is nothing in comparison to the advantages to be gained. It is well known to all of us that in obtaining higher temperatures, it is necessary to recuperate or to regenerate with producer gas, whereas it is possible with blue water-gas to attain the same results in heat-

ing as with the richest natural gas. If we are to imagine for a moment that natural gas has disappeared entirely, we naturally ask what is to take the place of it in forging operations, welding, and other high temperature work, where producer gas is obviously unsuited. This problem has already been taken hold of by two or three local concerns, one of which is about to operate a blue water-gas plant having a capacity of 1 000 000 cubic feet a day. Another large concern is said to use blue water-gas exclusively in one of its isolated plants. In England, where it is presumed this matter has been carefully considered, there exists a tube-mill employing 30 000 men, which uses blue water-gas fuel throughout. The name of the concern is Stuart & Lloyd, Ltd.

It seems unnecessary here to dilate upon the advantages of gas over other forms of fuel. Three or four advantages may be named, however, which may possibly have escaped the attention of those who have been too busy to follow the recent developments in the handling of gas fuel. Systems are available now by which direct-fired furnaces, such as are used for welding, forging, annealing, heat treating, etc., are supplied with gas, under suitable pressure, which automatically entrains the exact quantity of air for consuming it completely Such a system does away with the necessity for air piping or for air blowers. It also makes stacks or any sort of draft upon a furnace unnecessary and in fact undesirable. Flame is completely eliminated from furnace chambers. The composition of flue-gas is thoroughly under control and may be oxidizing, reducing or neutral, as desired. The temperature of such a furnace is always under the control of a single valve. The adjustment by means of which the proportion of fuel and air is regulated, rests with those who are responsible for economic operation and not with the unskilled labor. Such a system as has been outlined has been responsible for unbelievable results in the improvement of work heated, and in economy of fuel, time and labor.

Undoubtedly fuels other than gas will receive more attention in this district in the future but with the improvements which have been effected in the handling of gas it seems likely that the inroads upon gas consumption will be greatly checked. At the

present time many factory managers are congratulating themselves that they have found it possible to turn to coal as fuel and to achieve success with it. Their success however, has not yet been measured in any true light, because most of it was attained during the war period and in these times almost anything has been made to pass.

MR. B. M. HERR:* I should like to ask Professor Crabtree whether in selecting a fuel for industrial heating the temperature that is desired in the furnace has not a great deal to do with the matter. I happen to have had a very interesting experience with a producer-gas plant of the Hyatt Roller Bearing Company, where clean producer gas is used for hardening and tempering rolls. They started with a little 250 horse-power producer plant and worked the application out in a number of little furnaces and it was so satisfactory that they now have 2000 horse-power of producers there. The temperatures desired are about 1600 degrees F. and everything is working out very satisfactorily with producer gas. While I was engaged in that work there we figured out a theoretical curve (See Fig. 1) relating producer gas quantities to city gas quantities, which latter they were using at the time. This showed that at low temperatures producer gas was very economical as compared with city gas, while at higher temperatures there was so much loss, due to the large volume of producer gas products of combustion passing through the exhaust, that it became an uneconomical proposition. I would like to know if you have any information along this line.

PROFESSOR FRED. CRABTREE: I think there can be no doubt about the correctness of Mr. Herr's statement. When a moderate temperature is desired, and particularly a uniform temperature over a comparatively large area, producer gas without regeneration may be very satisfactory. For high temperatures, with a gas of low B.t.u. value, the regenerative or recuperative system must be used; and with the regenerative system it is possible to get any temperature that the bricks will stand, at the same time getting

*District Sales Manager, Edward Valve & Manufacturing Co., Pittsburgh.

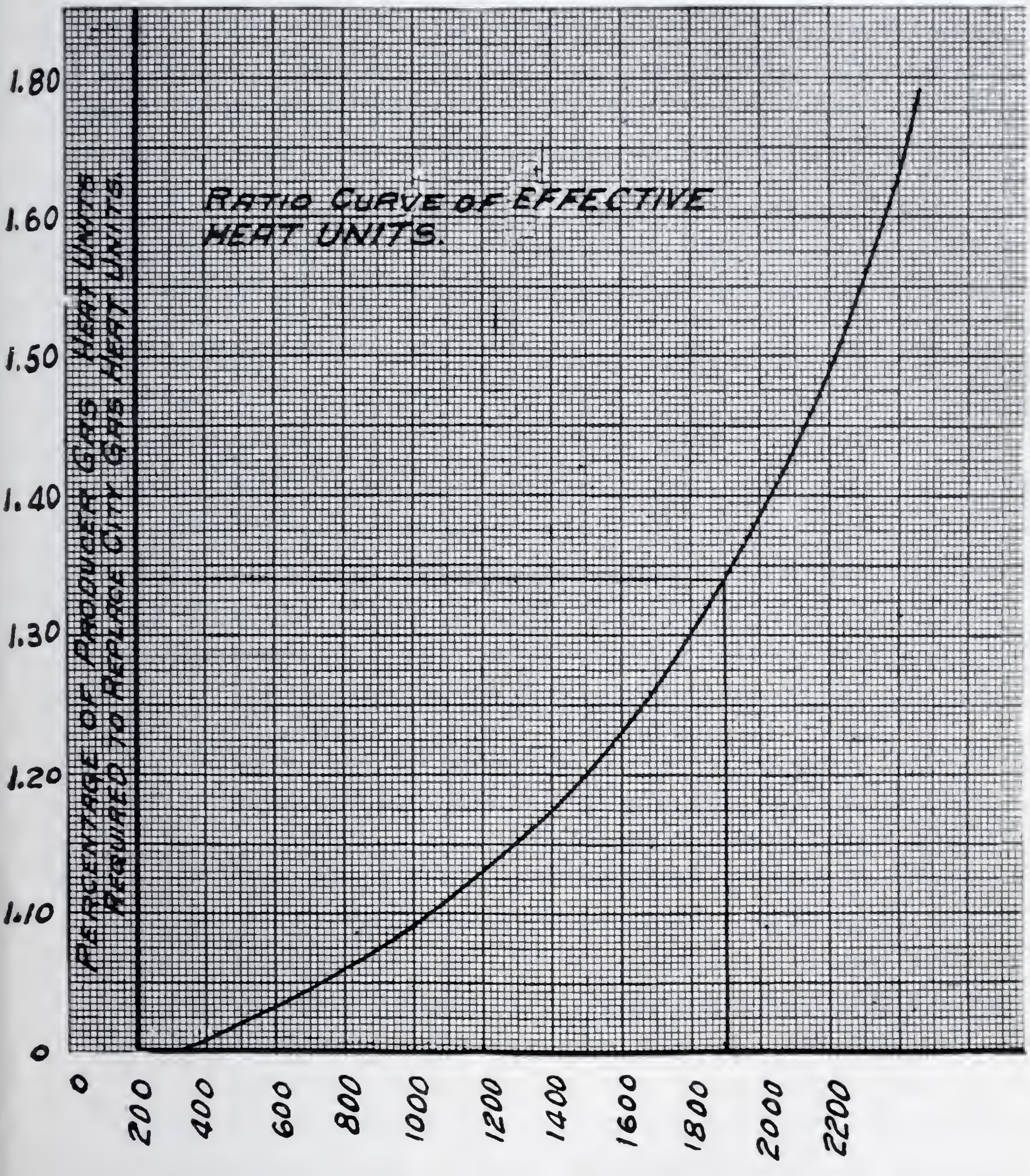

Fig. 1. Ratio Curve of Effective Heat Units; Producer Gas to City Gas.

fuel economy. The surface combustion system of burning, without regeneration, should give a somewhat higher temperature than direct burning in the ordinary way, because it permits or affords complete combustion without an excess of air. Ordinary gas burning methods do not give complete combustion of the gas without an excess of air, and of course this excess lowers the temperature. But I have no knowledge as to just what results may be obtained in practice by surface combustion methods.

MR. A. E. BLAKE: I might say for the gentleman's information that in direct fired furnaces, with producer gas, the highest we have been able to get with surface-combustion firing equipment is about 2100 degrees F., but the furnaces operate continuously at from 1800 to 1900 degrees.

MR. GEORGE L. NORRIS, *Chairman:* Is there any gentleman present who is prepared to discuss the industrial use of by-product gas? Mr. Taussig, will you contribute something?

MR. J. H. TAUSSIG:* I came here from Philadelphia on rather short notice. The United Gas Improvement Company, of which I am a member, operates water-gas plants on a large scale, having plants in about 50 different cities. Our company has also built about 80 per cent. of all the water-gas plants in this country. Naturally, when we heard that natural gas was giving out in Pittsburgh and you were looking for some way of making a fuel gas, I jumped on the train.

I came rather prepared to have my guard up. I expected Professor Crabtree to tell us there was nothing like producer gas. I tell you frankly we are rather surprised to see the close comparison between water-gas and producer gas. We were called in—only as an afterthought—when the engineers of the United States Steel Corporation were contemplating building a plant on Neville Island. I understand the engineers hardly knew what water-gas was. To our surprise we found that we could approach in cost, including interest and depreciation, so closely to producer gas that I understood they had practically decided to put in a water-gas plant instead of a producer-gas plant. Among the other advantages, in addition to those mentioned, are a central plant with a distributing system with a holder to receive the gas for a working storage; the ability to handle a gas free from sulphur for heat treatment—a point that has not been brought out, for to purify a large quantity of producer gas means a very large purifying apparatus, while with water-gas it is very much easier to do this. I know in many industrial plants, a gas free from sulphur is an important feature.

*Engineer of Design, United Gas Improvement Co., Philadelphia.

Professor Fred. Crabtree: I would say that my estimate for the cost of blue water-gas was higher than the figures given by Mr. Blake and Mr. Taussig, and was an approximation as close as I could get. Having no access to a detailed cost sheet, the next best plan seemed to be to apply to a friend who is making water-gas on a large scale. His estimate was that blue gas could be made, in the size plant I was considering, at from 15 to 17 cents per thousand cubic feet, overhead charges not included. Coke was figured, I believe, at about $3.50 per ton. Recently, he expressed an opinion that with a larger plant and with waste-heat boilers, etc., it might be possible to reduce the cost; perhaps close to 12 cents per thousand cubic feet. Possibly his plants may not have all the refinements included in the estimates of Mr. Blake, but they are probably not much out of date as to economy. I do not know on what information Mr. Blake's estimate was based. For myself, I usually try to get data from an actual operation when possible, to compare with engineering estimates. The latter frequently omit certain contingencies that arise in ordinary operations.

I would like to ask what Mr. Taussig considers the average B.t.u. value of water-gas made from coke.

Mr. J. H. Taussig: It is, as a rule, about 310 B.t.u.

Professor Fred. Crabtree: I would like to ask if blue gas is used in melting operations, for melting either steel or alloys.

Mr. J. H. Taussig: I am not familiar with the various installations around the country, but I understand it has been used very successfully in crucible steel work. It is a very satisfactory material for that purpose. They also use it in lead melting pots and apparatus of that sort. With a good burner you can get a very high flame temperature—as high as with any other gas. Most industrial operations, especially the small ones, are not recuperative or regenerative and it is not convenient to equip them in that manner. For this reason, water-gas is superior to producer gas on account of the higher temperature obtained.

MR. A. E. BLAKE: In connection with the different fuel gases, there are some considerations which seem to escape a great many people.

To make comparison between blue water-gas and natural gas as to heat content per foot—natural gas is 1100 and blue gas 300 B.t.u. The question at once arises—how are you able to say you can do the same thing in the temperature line, with one as with the other? If you burn natural gas you must use about 11 volumes of air. That gives quite a total volume of mixture. The heat content of that mixture will be about 96 B.t.u. to a cubic foot. If you have water-gas of 288 B.t.u. you will need about 2.14 of air to 1 of gas. The resulting volume is quite small. The heat content of a cubic foot of such mixture is about 91; so that the heat content per foot of mixture, which counts more than anything else, is very close together for the two gases. When you come to producer gas, if you have gas of 160 B.t.u., it takes about 1.3 cubic feet of air to burn it completely; but this mixture, due to the nitrogen which dilutes it, has a heat content of only about 72 B.t.u. per cubic foot; so that there is a decided falling off. Blast-furnace gas has about 99 B.t.u. to a cubic foot, and it takes about 0.7 foot of air, and the resulting mixture will have about 57 B.t.u. to a cubic foot.

MR. J. H. TAUSSIG: There is another thought that may be brought out. In plants having regenerators, higher efficiencies can be obtained with water-gas than with producer gas because it requires twice as much air to burn water-gas. If you can preheat twice as much air with approximately equal waste products, a lower outlet temperature is obtained, which means less waste and higher efficiency with the water-gas.

MR. CARROLL MILLER:* There appears to be no doubt that the maximum production of natural gas has been reached, and probably it will now begin to decline, but we cannot say absolutely at what rate the production will decrease. However, we are confident that natural gas in some quantities will be sold in the Pittsburgh District long after all present here have passed away. Nev-

*General Manager, Philadelphia Co., Pittsburgh.

ertheless, this need not concern our consumers, as the Philadelphia Company is already making manufactured gas and is preparing to build plants as rapidly as necessary to keep up its present volume of sales. As the proportionate amount of manufactured gas increases, the heat units in the mixture will necessarily decrease, but we feel sure that little more or no more gas will then be used for doing the equivalent service of straight natural gas at present, if our consumers will use the gas more efficiently. Our engineers are prepared to advise our customers regarding efficiency and regarding substitute fuels.

As in the past, in extremely cold weather our industrial consumers must use a substitute fuel, because the domestic consumers at such times require our entire output.

Author's Closure: I should like to express my appreciation of the data and estimates given by Mr. Blake. Not being privileged myself to submit such an estimate as he has given, I am very glad that he has done so, for I am sure many members of the Society will find it interesting.

THE MANUFACTURE OF STEEL FOR ORDNANCE MATERIALS IN ENGLAND AND IN FRANCE

By Major F. F. McIntosh*

The object of this paper is to present to the members of the Engineers' Society of Western Pennsylvania a summary of the observations and impressions obtained on an inspection trip made to the steel mills of England and of France.

It was my good fortune to be detailed as a Liaison Officer from the Inspection Division of the Ordnance Department to visit England and France to study, from the point of view of a metallurgist, the methods of inspecting and of manufacturing ordnance materials in those countries.

It was felt that a study of this kind would help materially with the production of munitions in this country, and it was hoped that such a study would show that it would be safe to ease up on our requirements and methods of inspection.

The years of experience which our Allies had acquired under the pressure of war would certainly indicate lines along which it would be safe to lower requirements and hasten production. It was felt that we had gone as far along these lines as we dared without carefully consulting and studying their practice and experience.

The results of this phase of the work can be summarized in a very few words. It developed that there were very few lines along which it would be safe to ease up on inspection or requirements, and that there were lines along which our inspecting and testing were not as searching as those employed in England and in France. It was evident that the general quality of steel being produced in those countries for ordnance materials was much higher than the material which we had been inspecting at home.

This fact was particularly noticeable in the case of steel for cannon. It was rendered more striking by the realization that the manufacturers had been under the pressure and strain of war conditions for four years.

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In this country the feeling that, in case of war, a million men would spring to arms over night had been so relied upon in certain circles that all efforts on the part of the Ordnance Department to prepare for war had been completely suppressed. When war was declared, therefore, it was necessary to create an organization and establish highly specialized manufacturing industries on a mammoth scale. The task was so great that our existing facilities were negligible. Plans were made to handle this gigantic task according to schedules which correlated the different branches of the service. These plans were largely based on the time necessary to train the men, and on the shipping space available. The Ordnance Department then buckled down to the task of producing unheard of quantities of highly specialized material and producing it on time.

When plans were made to send ordnance officers of the Inspection Division abroad to study the manufacture and inspection of ordnance material in England and in France, it was clear that we were coming into an enormous production in this country, and that we were going to run well ahead of schedule. It was to be the duty of the officers assigned to this foreign observation work to secure information as to the experience and practice of foreign governments as a guide for our inspection work. They were to look for improvements and for short cuts which would be safe.

The reception extended to us in England and in France was more hearty and cordial than we had hoped for in our most enthusiastic dreams. It was at a time when our men at the front had turned the tide of war, and were showing the world that they were unexcelled as fighting men. It was only a question at that time of how long it would take to finish the job.

Our liaison mission arrived when the enthusiasm for our army was at its height. We were given privileges which we could never expect to receive again. Everything was thrown wide open to us, and every effort made to aid us in our work.

The general impression obtained in both England and France was that they had acquired the art of maximum production with

minimum effort, hurry and expense; that they had discovered the critical and essential points in their work and that they were not wasting time on non-essentials.

An American engineer might find much to criticize in the arrangement and layout of their steel-mills, but careful study would disclose the fact that they were turning out a very high grade product, and that the amount of steel rejected or wasted was small. He might criticize their war work buildings, but he would be forced to admit that in many instances they could be put up in less time, would cost less money, and would serve the purpose as well as the buildings which he has made for the same purpose. I believe that he would discover this fundamental difference between the work here and the work abroad.

Abroad, the Hun was battering at their very doors before our Allies realized that war was upon them. A rapid but careful survey of resources and facilities was made by competent men. The facilities immediately available for making war materials were put to work under heavy pressure. Other facilities were modified to do that work which they could do with the least amount of change or remodeling. Entirely new facilities were created by the shortest possible methods. The saving factor in both countries was that it had been the policy of their respective governments in peace time to foster the manufacture of ordnance materials in industrial concerns, and to foster in these concerns competitive design of ordnance material. As the result of this policy, each large manufacturing concern had a nucleus of men skilled in the production of ordnance. This was the yeast which leavened the loaf. Without this leaven the Hun would have conquered.

In this country we had time to see what was coming. That we did not use this time is another story. However, when the time did come when we were forced into war, we had been given full opportunity to realize the magnitude of the task before us. Everything was planned for the gigantic task before us, and the plans of the different branches of the service were correlated so far as was possible. We did take what little was available and tried to fit it into the scheme, but we did not strain for immediate production as our Allies had been forced to do. Our aim was to get a big machine producing on a schedule basis.

The fact that one branch of the service—and it is a branch of which we should all be proud—delivered finished soldiers far ahead of schedule, can be interpreted to read, by those inclined to be careless in drawing conclusions, that the Ordnance Department was far behind in its schedule. As a matter of fact, ordnance materials were considerably ahead of schedule, but not so far ahead as the other department which was making soldiers. In the ordnance work there was little or nothing to start with. In the case of soldiers, the Plattsburg camps had supplied the yeast which leavened the mass and produced an army in an incredibly short time.

The more I consider these two facts the more firmly I become convinced that they contain two highly important lessons for us. If we continue and develop the Plattsburg idea we will always have a yeast which will produce an effective army in an incredibly short time. If we foster competitive design and the production of ordnance materials in industrial concerns we will have nuclei which will produce ordnance materials on the vast scale required by modern warfare. In no other reasonable way can we expect to be ready to meet such demands quickly. I beg your careful consideration of this fact.

The ordnance machine which was planned in this country was one which, by its very nature, would dribble out a small production during the short tuning up period and then burst into full speed giving enormous production. It had burst into full speed when the armistice was signed. In spite of the impression that our Allies had acquired the art of maximum production with minimum effort and facilities, one could not help being a bit proud of the size and completeness of the machine which was coming into production at home. There were other general impressions which I wish I could take the time to convey to you. They are, however, entirely foreign to our subject. As a native of Pittsburgh, I cannot let this opportunity pass without calling your attention to one impression which met me at every turn.

You have all experienced the feeling of depression which comes over one upon returning to Pittsburgh after even a short stay in other parts. After a few days stay here in our old environment and atmosphere, this feeling of depression disappears;

we become hardened to or oblivious of the smoke and dirt, and we are contented with our filthy atmosphere, and dirty unattractive surroundings. Now I do not contend that towns like Sheffield, Newcastle, Manchester, etc., are clean smokeless towns, but I was strongly impressed with the fact that they are not as careless or indifferent in regard to smoke and waste in general as we are, and that they have succeeded in doing much more than we have to reduce the amount of smoke. In France they have done wonders in the elimination of smoke and dirt, and in general conservation. Take a big plant like Le Creusot where everything was so clean and smokeless that it was difficult to realize that one was in a large iron and steel producing center. It is not an accident that they are clean, it is the result of study and work by their engineers backed by company management and public opinion. Some day I hope we will realize that it pays to be clean. I never expect to see the day when we will be clean for any other reason.

The steel making members of this Society are all familiar with much that has been written of English and of French steel making practice. Some of them have probably made steel in those countries. I do not propose to get up here and try to tell them how to make steel. I believe, however, in the great value of an interchange of ideas, and I know that we will both get something out of this meeting, if they understand the point of view from which I observed the foreign practice and are willing to approach and discuss the question with an open mind. I am even tempted to make assertions, which I know will evoke comment, merely for what I will get out of the resulting discussion.

My point of view, in visiting these foreign works, was that of one who had been brought in contact with all of the sick and diseased steel which was presented to the Ordnance Department and detected by its inspectors in the field. One in this position is apt to acquire an exaggerated idea of the actual percentage of sickness and mortality. Careful analysis of all reports showed, however, that in certain lines of work there was an alarming amount of unsatisfactory material being manufactured, an amount which meant a large economic loss and a serious delay in our program. My attention was naturally centered largely on those lines

of work with which we were experiencing the greatest difficulties. My remarks, therefore, will be directed to those lines and should not be taken as intended to cover the entire field of steel making.

This was the condition which I had known at home, and I was keyed up to find a remedy abroad. The most obvious remedy which I found, the one which was outstanding first, last, and all the time, was the care with which the steel was made. The final results justified this care from the point of view of cost of finished material, of quality of finished material, and of the amount of material produced.

To watch carefully the operation and the product of an English concern turning out monthly over 300 finished cannon of all sizes, was an inspiration. Some of our experts in this country would say that our Allies take too much time to make a heat, or that they make the steel too hot, or that they teem it through too small a nozzle, or that they never will get sound, clean steel unless they bottom pour it; or they might say that the English are not careful enough in their heat treatment of the steel. To watch the physical testing of this steel, and be confronted by the figures on production would completely silence their criticism.

I should say that the most striking feature of the foreign steel making practices is the fact that they make their additions in the furnace and test carefully to make certain that the steel is right before it is taken out of the furnace. They will not take sick metal out of the furnace and rely upon medicine in the ladle to cure it before it solidifies in the mold. This is true of the English acid practice and of the French acid and basic practices. I cannot say anything in regard to English basic practice, as the only basic practice which I watched in England was an occasional basic furnace making acid remelting scrap from nickel and nickel-chrome turnings.

It would not do, at this time, to attempt to describe in detail the practices followed at the different plants studied in England. There are differences from plant to plant, and from melter to melter in the same plant. I will try to make a summary of the practices, characteristic of all of the English work.

Additions are never made to a heat until it is completely melted and is hot. An effort is made, particularly on heats con-

taining nickel-chrome scrap, to melt with a neutral or a reducing flame. At one plant the temperature of every heat is checked by means of an optical pyrometer, and no additions are made to the heat until it has reached the temperature of 1600 degrees C. At this same plant the temperature of the metal as it leaves the furnace is observed by means of an optical pyrometer and is regularly recorded. The management of this plant realizes fully, I believe, the limitations and shortcomings of the optical pyrometer, but claims, however, that it is highly advisable to use it. Its value is considered to lie in the moral effect which it has upon the workmen, and in the permanent record which it helps to give of the conditions under which each heat was manufactured. Experience has shown that the workmen first scoffed at the instrument, then became curious about it and tried to check it against the human eye, and finally reached a point where they have enough respect for the pyrometer to consider it as a check upon their ability to judge temperature, and show considerable pride in being able to foretell by the eye what the reading of the pyrometer will be. The optical pyrometer, usually of the Fery type, is used much more for all kinds of work in both England and France than is the case in this country.

It is universally considered important to have heats well melted and hot before any additions are made. It is considered of even more importance to have the heat thoroughly deoxidized and hot before tapping. Any free iron oxid in the slag at the time of tapping is considered to be fatal, and the slags in some practice will run as high as 60 per cent. silica. The hot, highly acid slag has a deoxidizing effect on the metal. The slag should be hungry for bases, and if analyses of the slag before and after the addition of deoxidizing agents show that the slag has been deoxidized by the additions, then it would be said that the slag had not been sufficiently acid at the time the deoxidizers were added to the metal. The condition of the slag is watched with as much care as is the condition of the metal. Towards the end of a heat the slag should not show any dark colored streaks. These dark colored streaks or spots in the solidified slag are supposed to indicate that the slags contain free oxids. With free oxids in the slag the metal could not be properly deoxidized.

The deoxidizers are all added to the metal in the furnace, and samples of metal are tested by forging before the heat is tapped from the furnace. The old method of taking test samples which are allowed to cool under a layer of slag is quite generally followed and they seem to consider the appearance of the surface and fracture of this test a reliable index of the condition of the heat.

The ladles are merely dried out by means of wood or coke fires, and would be considered as cold ladles in this country. Yet a 40- or 50-ton heat of steel will be teemed through a ¾- or ⅞-inch nozzle without leaving a skull in the ladle. It requires a hot and thoroughly deoxidized metal to meet this requirement. Observation of the finished machining operations and the physical testing of these steels shows a metal very free from inclusions of foreign material. There is a marked difference in this respect between the English steels and the American made steels; a difference in favor of the English steel.

It is the belief of well informed English steel makers that deoxidation in the ladle brings about chemical reactions which result in non-metallic materials, such as silicates, oxids, sulphids, etc. These reactions, giving non-metallic materials, are still going on as the metal solidifies, and this reaction results in numerous small non-metallic inclusions scattered all through the metal. The fact that inclusions of this kind are much more numerous in American steels than in English steels indicates the soundness of their contention. If our cannon steels were forced to meet bending and impact tests as are the English steels, this matter of small foreign inclusions would immediately become a matter of grave importance.

The outstanding feature of the English ladle practice is the use of small nozzles, and, in many cases, the use of more than one nozzle on a ladle. On heats running up as large as 80 tons, nozzles from ¾ to 1 inch in diameter will be used. The fact that large heats are teemed through such small nozzles without leaving a skull in the ladle indicates clearly the temperature and character of the steel. In order to teem large heats of steel through small nozzles, many manufacturers resort to a composite nozzle; that is, a nozzle of which the forward part, or the part towards

the outside of the ladle is made of magnesite and the inner part is made of clay. These nozzles are made in two pieces and fit together. I have measured a ¾-inch nozzle of this type through which a 40-ton heat of steel was cast, and the magnesite portion of the nozzle was practically of the original size. It is very common, but not universal, practice to use two stoppers and nozzles on a ladle. In such cases a ¾- or ⅞-inch nozzle is the nozzle through which the heat is to be teemed. The second nozzle is held for an emergency, and will vary from 1¼ to 2 inches in diameter.

All of the large work is top-cast, and bottom casting is resorted to only in cases where it is desirable to secure a particularly good surface on the ingot, or to cast a large number of small ingots at one time. It seems to be a general belief of the English steel makers that bottom-cast ingots contain more inclusions of foreign material and are less sound than the top-cast ingots. In one instance I was shown the results of a series of experiments on bottom poured steel for axles, which gave from 8 to 10 per cent. rejection of material for dirty steel. The same material, top-cast, gave a rejection of about one-tenth of one per cent. for dirty steel.

On all large work, hot tops are used and the ingot is placed on a bottom plate containing a good-sized pouring basin.

The question of inverted ingots for forging work of this kind has resolved itself largely into the question of the character of the particular forging for which the ingot is to be used. It is generally conceded that an ingot cast with the large end up and hot top will give the maximum degree of soundness along with the maximum horizontal extension of segregation. The same casting, with hot top and small end up, gives less horizontal extension of segregation and confines the segregation and unsoundness more to the vertical axis of the ingot.

The English are carefully studying the design of ingots with reference to the character of the metal in the finished forging. They realize that there are some factors more important than the percentage of reduction in forging.

I fear that our specifications contain requirements—such as a requirement of a four-to-one reduction in forging—which are matters of tradition and inheritance, rather than scientific prin-

ciples. There is evidence that our requirement as to reduction in forging is one of these traditions, and that it does not work to give us the best possible steel in the finished gun.

The English method of attacking this problem is largely by means of taking sections of finished forgings, and also sections of ingots, and etching them with an acid cupro-ammonia reagent which displays to the unaided eye the original ingot structure in the ingot itself, or in the finished forging. This is a very interesting line of work which is giving valuable results to those who are following it up. Attached to this paper is a description of this method of etching as used in the Naval Inspector of Steels Laboratory at Sheffield, England.

It is astonishing how this method of etching and study brings out facts which were entirely overlooked by those who were relying on the microscope, or on the physical test for their information in regard to the metal. I should like to urge strongly this line of research upon the members of this Society, and will be glad to tell them what little I can about the work along this line over there.

The most striking feature of the English forging practice was the heating of the metal for forging. In all cases, forgings are heated in coal- or gas-fired furnaces. These furnaces give a soft, even heat without excessive scaling of the forgings, or spotty heating, or danger of overheating.

To my mind, there is no room for dispute as to the relative value of coal or gas for this work as compared with oil. I believe that the sharp cutting flame of the oil-fired furnace has been the source of a large amount of trouble, and the cause of injuring much steel in this country. This sharp cutting flame is not only hard on the metal, but is very destructive to furnaces, whereas the soft, even heating of the coal- or gas-fired furnaces gives metal in which the heat is well soaked through, metal which has not scaled badly, and gives furnace life much greater than can be obtained with the best oil-fired furnaces. In many instances waste-heat boilers were used to very good advantage on the forging furnaces.

It is common practice to use crescent-shaped or V-shaped dies for forging but, in one or two instances, large manufacturers were using straight-faced dies with excellent results.

The temperature of forgings was rather carefully watched at all places. In most cases the workman's eye would be checked up from time to time by use of an optical pyrometer.

It was the general custom to heat the forging to about 1250 degrees C. With the use of coal-fired furnaces, there was much less danger of local or general overheating of this work than would be the case with oil, working at this temperature. It is very easy to understand how metal heated to 1250 degrees C. in an oil-fired furnace could be locally damaged by overheating, or by superficial heating.

Some of the most successful manufacturers were careful to stop all work on a forging when its temperature had fallen to 800 degrees C.

One metallurgist held very strongly that it was his belief that the temperature at which forging should be stopped was not so much a matter of where the critical point of that steel lay, as it was a matter of the physical strength and characteristics of the metal at different temperatures. He felt that the danger point in forging would vary with the character of the steel with reference to its chemical composition, rather than with reference to its critical point. This is an interesting belief which is grounded on experience rather than on theory. The general experience of all forgers seem to be that forging at too low a temperature might cause internal tears in the metal.

I believe that our English cousins would be amazed at the beautiful equipment and at the facilities which we have for heat treatment in this country. They are old hands at the heat treating game, and do not take it quite as seriously as we have done. Their experience seems to point to the fact that if they make good steel and forge it properly, they will have a wide latitude in the forging and in the heat treating.

I should say that more than 50 per cent. of the cannon forgings are heated in horizontal furnaces. The quenching is always done in a vertical position. The pyrometric equipment on these heating furnaces is very simple indeed. In most cases it consists

largely of the workman's eye, aided either by water pyrometers or an optical pyrometer.

For drawing or tempering work, pyrometers are much more generally used. Base metal couples are used for this work. In many instances the forgings are turned by chains during the tempering operation. The general practice is to inform the workman that such and such forgings are to be heated to 1600 degrees F., or whatever the desired temperature may be. The workman places the forgings in the furnace, examines them from time to time, and when he believes that they have about reached the desired temperature he will check his eye either with an optical pyrometer, or by means of the Seaman water pyrometer. Occasionally thermo-couples are used for this work, but nowhere will one see the elaborate pyrometric equipment which is to be found in this country.

When the forging has finally reached the desired temperature, it is kept at that temperature for a short time, varying from 15 to 30 minutes, removed from the furnace and quenched. In general, the quenching temperatures used are higher than those employed in this country, and the time of heating is much shorter. A comparison of their results with ours would indicate that in most cases we have followed theory too closely. In the horizontal furnace I have seen a six-inch tube heated for quenching in two hours, and 18-pounder tubes in an hour and a half. At this particular plant the workmen were instructed to heat the forging to 850 or 900 degrees C.

I believe that there are at least two dangers in our practice on this work which are completely avoided by the English practice. By our practice of a long slow heat, and an effort to heat the forging just above its critical range for quenching, we are in danger in two respects:

1. By using too long heating time we may bring the forging above its critical range and hold it there for a long time, which would result in coarse structure;

2. By using a temperature as we do, just above the critical range, we may not have the entire forging above the critical range when it enters the quenching medium.

Either of the above results gives unsatisfactory metal.

On the other hand, the English practice—short time in the furnace and temperatures well above the critical range when it enters the quenching medium—insures that the metal has not been held for a long time above its critical point, and results in less free ferrite in the quenched metal. The higher temperatures used in English practice are not sufficiently high to cause a serious coarsening of the structure during the short time they are held at that temperature. There seems to be very little fear of rapid heating injuring a forging which has been annealed and rough machined. The annealing has relieved strains and the rough machining has removed surface conditions which might promote cracking or tearing.

"The proof of the pudding is in the eating thereof." Examination of the records of the Sheffield District for the month of September, 1916, showed that 89 per cent. of the cannon forgings submitted to the Government for test, passed on first test. These figures covered over 5000 forgings. In this country the average was less than 60 per cent.

The methods of physical testing as followed abroad are more searching and exacting than those employed in this country. I hope to see these methods adopted in this country under peace time conditions, for they will force the steel makers to a higher development of their art.

The foreign governments are not willing to accept high-grade ordnance material, such as cannon forgings, solely on the result of tensile tests. It has been their experience that tensile tests are not sufficiently searching to show up all the characteristics in the metal, and I have witnessed in their testing laboratories several instances of material which passed the tensile test and failed on bending and on impact tests.

The bending test is a test which they have used for a long time, and one with which the manufacturers are thoroughly familiar. So far as I could find, the manufacturers all agree that it is a good test, that it is a fair test, and that metal which will not meet the bend test should not be accepted.

The impact test, on the other hand, is of more recent origin and not at all well liked by the manufacturers. It is a very searching test as to the quality of metal, and one which the Govern-

ments are imposing more and more upon the manufacturers. At the present time they are using it largely as a referee test on material of doubtful quality. Undoubtedly the time is coming when it will be a routine test which all high-grade material must meet. Both the manufacturers and the Government agree as to its searching character, but the manufacturers, as a rule, do not welcome its introduction. The Government is now preparing to incorporate this test in its specifications.

The performance of nickel-chrome steels under this test gives a striking example of just how searching it is. For example: A nickel-chrome steel which has been quenched and drawn and cooled in the furnace, or in air after the drawing operation, may meet the tensile and the bending tests with perfect satisfaction, but will fail under the impact test. The same steel quenched and drawn under the same conditions, but cooled rapidly in oil or water after drawing, will meet all of the tests, including the impact test; that is, the impact test is the only one which is searching enough to bring out the differences between these two steels of the same composition—steels which vary in their ability to resist shock merely as a result of the heat treatment which they have received.

The universal practice abroad of cutting off a disk of test metal from the end of the forging has so many features in its favor that it is difficult to understand why we still persist over here in removing the test piece by trepanning. Of course, this criticism of our method of taking test-pieces does not hold where the test specimen is a longitudinal specimen.

The disk of test metal saves time and simplifies the sampling of the forging, saves time in preparing the test-bars, gives a better opportunity to determine the character of the metal in the forging and reduces the time which the forging is held up for test.

Careful observation of the physical testing and of the machining operations, disclosed the fact that there was very little defective steel being produced. The defects with which we are familiar in this country were known there, but they occurred in such a small proportion of the work that they did not present a serious problem.

The most common difficulty appeared to be with forgings which failed on the bend test. Failure of this kind usually gave a banded fracture on the broken test piece. Frequently, on forgings of this kind, the tensile tests would be satisfactory but would show a slight tendency toward a banded fracture. There are some differences in opinion as to the cause of this banded fracture. Some metallurgists claim that in all cases where the banded fracture occurs, the steel would be found to contain inclusions of foreign material. Those who held this point of view claim that the difficulty could not be remedied by heat treatment. Certain manufacturers quite naturally held a different point of view on the subject, and their point was well sustained.

I was shown by some of these manufacturers, miscroscopic studies of the steel which gave the banded fracture, and the evidence presented clearly indicated that it was a segregation such as is quite common in nickel steel. It was a segregation unaccompanied by appreciable amounts of foreign material, and one which they claim could be and was frequently remedied by drastic heat treatment.

Those who hold to the foreign inclusion theory claim that the reason forgings of this kind pass tests after heat treatment is that the test pieces on retest are taken in a new portion of the metal and the portion which happens to be free from foreign material. It is one of those interesting problems over which metallurgists will develop warm discussions for years to come, unless a careful and exhaustive investigation should bring out a well defined solution of the difficulty.

The English manufacturers were familiar with the defect which in this country is called a flake. In the Sheffield district it is spoken of as a "zed" fracture—"zed" being the English for the letter Z, standing for an unknown quantity. This defect is of rare occurrence, but most manufacturers had evidently met with it occasionally. There seem to be be almost as many explanations for the defect as there were metallurgists who had experience with it. There was only one point in which they all seem to agree and that was the fact that it is associated with inclusions of foreign material.

Careful observation of the machining, and particularly the finished operation on the English forgings, disclose a remarkably clean metal free from sand splits and slag inclusions. The cleanness and freedom of the English steels from inclusions, when compared with our American steels on the same class of work, make it very doubtful if our steels would meet the bending and the impact tests which the English steels are meeting. It requires a very clean steel to meet these tests.

The point which interested me above all else in the French steel making was the fact that under the pressure of war the French had been making some of their cannon steel in basic open-hearth furnaces. As far as I could learn, the steel so made was proving entirely satisfactory.

In order to make satisfactory high-grade steel in the basic open-hearth furnace, the French had developed a method of handling the furnace which resembled in many ways the acid practice. In their basic practice for steel of this kind, the steel was deoxidized and additions were made in the furnace. The metal was never taken out of the furnace until it was demonstrated by chemical and by forging tests that it was thoroughly deoxidized metal. The only additions which were made in the ladle were small amounts of ferro-silicon. Most of their ferro-silicon was added in the furnace.

In order to operate a basic furnace under these conditions, it was necessary to remove a greater portion of the slag before any effort was made to deoxidize the metal in the furnace. I believe that the use of basic steel for high-grade forgings of this kind is a step in the right direction.

I should like to see the methods of testing ordnance steels developed to the point where the Ordnance Department can rely entirely upon its physical and chemical tests for the determination of the character and suitability of the metal for the purpose for which it is to be used. I believe that it is altogther feasible to develop the Department's testing methods to a point where this is possible, and where it will be possible to eliminate all unnecessary restrictions upon the manufacturer. Under these more or less ideal conditions, the manufacturer would be free to make the steel in any kind of a furnace which he should choose. He

would be free to cast it, to forge it, and to heat treat it in any way that he should think best, and the final test of the Ordnance Department would establish whether or not the material was satisfactory for the purpose for which it is intended.

This elimination of process inspection and requirements may sound very attractive to the manufacturer, but he should stop and consider the fact that it would mean tests much more searching than the ones which he has been facing. I am convinced that much of the steel which is being accepted on tensile test under present specifications would fail if subjected to bend and impact tests. These two tests are very searching as to the condition of the metal, and the presence of inclusions.

French acid open-hearth practice does not differ materially from the English, except that some manufacturers seem to be even more particular about the condition of the slag than were the English steel makers. I found French slags in some instances running as high as 65 per cent. silica, and when samples of the slag taken during the making of the steel showed a black streak, the slag was considered to be too high in free oxids.

The French were using nozzles somewhat larger than those used in England. The French practice seemed to vary between 1 and 1¾ inches, and it was almost a universal practice to teem through some kind of a basket. The steel was what we would call very hot steel and left no skull in the ladle. All large work was top poured with hot tops. Bottom pouring was used only for nests of small ingots where it was particularly desired to secure a good surface on the ingot, or where it was desired to save time in teeming.

One of the manufacturers was bottom pouring 20 ingots at one time. These were individual ingots, each one to be worked into a tube or jacket for a 75-mm. gun. This is the only instance in either country, where I found bottom casting employed for cannon forgings. The same general opinions seem to be held in France in regard to bottom pouring as were held in England.

Steel for large forgings is usually heated to about 1150 or 1200 degrees C. for forging. These temperatures in most instances are checked from time to time by means of an optical pyrometer.

The general practice in France seemed to be to heat the steel somewhat more slowly for quenching than was the practice in England. For example: On 155-mm. gun tubes, three hours were taken to bring the tube up to temperature, and it was held at that temperature for about 30 minutes. The quenching temperatures used were, as a rule, higher than those which were being employed in this country. It is quite common to find 850 degrees C. as the temperature for quenching, and it was generally felt that where this temperature was used, 50 degrees C., one way or the other, made very little difference. Most of the quenching was done in water.

The French regularly require a bending or impact bending test, and their experience with this test parallels that of the English; i. e., steels which are not in the proper condition, or which contain numerous small foreign inclusions may pass on the tensile test, but cannot pass the bending test.

The Charpy impact test is used merely for special investigation and is not a regular inspection test except upon material for aeroplanes.

When I attempt to summarize the situation from the point of view of an ordnance officer, I hope that it will be definitely understood that I am merely giving the personal opinions and ideas which have developed as a result of service in this country as a metallurgist with the Inspection Division of the Ordnance Department, and as a result of service as a Liaison Officer abroad. I regret to say that no official sanction or weight is to be given to any of my observations or ideas on the subject.

Observation of the machining and testing of ordnance steels here and abroad has convinced me that our Allies are making better steel than we are. This is particularly true of steel for high-grade forgings, such as cannon forgings. The fundamental reason for this difference lies in the manufacturing conditions under which steels have been produced here and abroad. In this country the plants are designed for tonnage, and the work of our furnace men is measured by three gages. The first is tonnage, the second is cost, and the third is chemical composition. Abroad there has been a fourth gage. That gage has been a high standard of physical qualities for the metal. I believe that we have

outstripped all competitors in tonnage and in cost. The chemical composition is largely a matter of natural resources. Our mistake has been in relying on it too largely as an index of quality. It is a necessary index of quality, but a very incomplete index.

We have been very lax in the use of the fourth gage, and our quality has suffered as the result of this laxness. We have done a certain amount of physical testing of our steels, but it has been of a very superficial character. It has lacked the searching character necessary to force our steel makers to a top notch of quality production. If steel has failed to meet our simple physical tests, or has shown so obviously unsound that it could not be used, it was assigned to some other purpose or was scrapped, and the loss was taken as something to be expected. We have not been forced to trace the difficulties to their source and to remedy them, and we have not been forced to a high standard of quality.

There are two main reasons why it is advisable for us to advance the science and art of steel making along lines of improved quality.

The first reason is that, during the recent emergency, poor quality and defective steels have resulted in large net economic losses—loss of the steel, loss of the time, effort and materials to produce it, and loss of time and effort in fabricating and machining the material which finally proved defective. Our tonnage per furnace may have been large, but our finished gun per furnace was very small. The net result is not in our favor.

The second reason was somewhat of a surprise to me. It grew in size and importance as I was thrown more and more in contact with officers who had engaged in actual fighting at the front. It points clearly to one of the features which we are to face in ordnance design. This second reason is the great importance of weight and mobility of ordnance materials of all kinds. There was a time when I felt that the extensive development of motor traction had made the matter of weight less important than it was in the days when reliance was placed on animal traction. Contact with officers of all services, officers who had experienced fighting service under all conditions, convinced me that weight was still a prime factor, and that we are going

to reduce the weight of ordnance material, just as far as we dare. This reduction in weight will mean that the steel maker will be called upon for increased quality and service from his product.

The relation between safety and quality is so self evident that I merely wish to direct your attention to it. You know the answer.

A summary of the situation from the point of view of an ordnance officer clearly points, therefore, to the fact that he should demand high standards of quality for metals submitted to him, and that he should employ methods of testing which are searching enough to demonstrate thoroughly the quality of the metal.

I hope that the steel maker in summarizing the situation will realize the value and the possibilities of improving the quality of certain grades of his product, and that by directing certain of his energies towards a high-grade product he will open up new commercial fields and will create a nucleus of highly skilled men that can be relied upon in case of war to produce high-grade steel for ordnance work.

He will realize, I hope, that he is going to face demands which will be more and more exacting as to the quality of his product. Its quality will be actually determined by searching tests which will establish its merits for the work which it must do. To compensate for the more searching tests which he must prepare to face on government and commercial work, he should expect less dictation and interference with his methods of manufacture and more aid from the Government in the solution of technical problems of a broad general character.

I went abroad feeling that we had very little to learn from the foreign steel-maker. What I saw over there did not lessen in any way the pride which I have in our own accomplishments in the iron and steel industry, but it did emphasize this point—a point which holds with most of our large industries. We must not allow our own great accomplishments to blind us to the good features of the work and methods of others. If we are to excel

and lead in keen competition which is before us, we must be ready to adopt the best features of our competitor's practice and excel him at his own game.

I hope to see the day when steel from Pittsburgh will outrank that from Sheffield in quality as well as in quantity.

APPENDIX

The following is the method of etching for macrostructure of steel as developed by Mr. J. C. W. Humphreys, Chief Chemist in charge of Naval Inspector of Steels Laboratory at Sheffield, England.

Etching—The solution is prepared by the addition of hydrochloric acid to Heyn's reagent. The most satisfactory composition for general work is:

Copper ammonium chlorid.......	120 grams
Hydrochloric acid (conc.).......	50 cc.
Water	1000 cc.

The exact proportion of hydrochloric acid appears, however, to vary somewhat for different steels, and is best determined by trial. Mr. Humphreys prefers to support the specimen so that the surface to be etched is horizontal, and to spray the solution on at frequent intervals for about 15 to 20 minutes. It may, however, be used by immersing the whole specimen in a bath of the solution. If used in this way the percentage of hydrochloric acid should in general be somewhat higher than that given above, and the surfaces not requiring etching should be protected from its action.

This reagent which appears to differentiate the same structures as those of Rosenhain and Haughton and of Stead, does so in a manner more suitable for macro work, and in such a way that direct reproductions of the etched surfaces can be obtained by a simple process of printing.

The solution, as in the case of Heyn's reagent, deposits copper upon the surface but in a somewhat different fashion. With Heyn's reagent the deposit is of a loose flocculent nature which can easily be removed by rubbing with a cloth or brush while the specimen is wet; with the addition of the acid, however, the nature of the deposit alters and the copper tends to come down as a fairly strong and continuous film which can frequently be peeled off the specimen in strips leaving the etched surface free for examination. It would appear that a very strong film indicates that the etching solution used contained too large a percentage of acid, in which case the action tends to emphasize, and eat into deep grooves, the scratches left after polishing, without a proper etching effect taking place at all; while a flocculent deposit indicates that the solution is too weak in acid and the proper contrasts are obtained only slowly, and at the expense of a very deep general attack.

Machining marks or file scratches always appear to interfere with the etch, and it is essential that all signs of them should be removed by polishing across with No. 1 or No. 0 emery paper. The scratches left by the emery paper are usually entirely obliterated by the etching, but any difficulty in this respect can be avoided by giving a preliminary attack with a solution of nitric acid in alcohol, or with neutral Heyn's reagent, until they have disappeared.

As stated above, the first attack should usually be continued for about 15 or 20 minutes, and the specimen then well rinsed with water. While still wet, a sharp knife blade is used to raise a corner of copper film, and the latter is then gradually stripped off until the surface is free. If any difficulty is experienced in removing the copper by mechanical means, all traces of it can be quickly and easily removed by immersing the specimen in the solution of ammonium persulphate in ammonia used for decoppering the bores of guns:

Ammonium persulphate	10½ ounces
Ammonia (sp. gr. 0.880)	1 pound
Water to make...............	1 gallon

After removal of the copper, the specimen is dried with alcohol and, if the etching is correct, it will be found that a marked pattern has resulted. The portions of the original ingot which were the first to solidify and hence contain a minimum of dissolved impurities, are eaten out; while the portions which solidified later (and which therefore contain an excess of dissolved impurities) are left standing in strong relief. As dried, the contrast between the hollows and the relief portions is not very marked, but if the surface is given a light polish with one of the finer grades of emery paper (No. 00 or No. 000) the pattern is very clearly revealed.

If required for examination of the etched surface a single attack is usually sufficient but, if the etching is to be produced by the process to be described below, then a deeper contrast is necessary and two or three attacks are generally required.

Printing—The strong relief pattern which is produced by the etching solution suggested the possibility of reproducing the effects by direct contact printing; i. e., by means of printers' ink and a press. While to obtain the most perfect results by such a process, it would be desirable to employ a proper printing machine, etc., it has been found quite a simple matter to produce very satisfactory results with apparatus obtainable in an office and laboratory.

It may be noted that there are two ways in which such an etched surface can be used for printing; viz:

1. The hollows are filled with ink, and the reliefs wiped clean; that is, the process used for copper engravings. 2. The reliefs are inked by means of a roller and the hollows left clean.

For simplicity and speed the latter process is much to be preferred, while, since it gives a print in which the segregated portions are dark, such prints are directly comparable with a sulphur print.

Mr. Humphreys' methods of making prints is as follows: The specimens are machined before etching, into the form of slabs with two parallel faces, one of which is etched. Ordinary printers' ink is applied to the etched surface by means of a roller made on the principle of the ordinary photographic squeegee, but with a somewhat greater thickness of rubber (an iron cylinder

covered with a length of rubber tubing stretched over all). A few dabs of ink are placed on a smooth sheet of glass or tin-plate, and the roller passed in all directions over the sheet until the ink is evenly spread out. Ink is transferred to the specimen by passing the roller alternately over the inked plate and the etched surface. The specimen is then placed face upwards on the base of an ordinary copying press, a sheet of glossy "art" printing paper laid on top, covered with a pad about ¼ inch thick made of thicknesses of smooth paper and finishing with a few thicknesses of soft blotting paper; and pressure applied.

By pressing the paper down on the inked surface with the flat of the hand, or by means of an iron roller, fairly successful prints have been obtained from specimens too large for the press.

The ease with which an even layer of ink can be applied to the etched surface would probably be increased by using an inking roller of large diameter covered with the special printers' composition of glue and treacle.

Since it would appear that the segregates left in relief by the etching solution are chiefly, if not entirely, marked by their higher percentages of phosphorus, the prints may conveniently be termed "phosphorus prints" in the same manner that prints obtained by means of acidified bromide paper are termed "sulphur prints."

DISCUSSION

Mr. W. C. Hawley, *Chairman*:* We have listened to a most interesting paper, and the subject is now open for general discussion.

I would like to ask if most of the heating is done in vertical furnaces.

Major F. F. McIntosh: No, the heating for forging is all done in horizontal furnaces. There was some vigorous discussion in this country as to the advisability of using forgings which had been heated in a horizontal position before quenching. I was interested to find that heating for quenching is done over there to a great extent in horizontal furnaces. Our specifications require that forgings shall be heated in a vertical position. The practice abroad indicates that this is an unnecessary requirement.

Mr. F. N. Speller:† What is the latest development toward the overcoming of erosion?

Major F. F. McIntosh: There has not been any particular development. Of course they reline.

There is some development along an unusual line, but that is more or less of a secret. But so far as concerns prevention of the erosion of an ordinary rifled gun, I found nothing. I do not believe they are making any effort to reduce erosion through the character of metal used.

Mr. G. D. Chamberlain:‡ Can you tell us something as to the development of increased strength?

Major F. F. McIntosh: The British resort extensively to the use of wire-wound guns and in this way make the metal in the gun work to better advantage and thus secure a stronger gun.

Mr. G. D. Chamberlain: You referred to the study of the size and shape of the mold with reference to the forging. In

*Chief Engineer and General Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

†Metallurgical Engineer, National Tube Co., Pittsburgh.

‡Metallurgical Engineer, Heppenstall Forge & Knife Co., Pittsburgh.

general, what line have they followed and to what extent could the mold be changed to fit the shape of the forging?

Major F. F. McIntosh: If you take a section of an ingot and study it you will find there is a section down through the center which is not quite the same material as that which makes up the main part of the ingot. The whole thing is to try to design it so that when it is trepanned, the central portion which is cut out represents the undesirable portion of the ingot. If, in the design of the ingot, you are guided entirely by the reduction in forging some of that undesirable central portion might come in the inner wall of the tube; that is, you get the worst material where you want the best. Most of the ingot molds abroad are hexagonal or octagonal in cross section and there is no general practice with regard to big end up.

Mr. Patterson: I happened to be interested in a concern which made three or four hundred guns for the English government in practically no time. When they started to take it up for our own government it took a year to make two. Do you think the English government is more lenient with the material?

Major F. F. McIntosh: I do not just see where the difference in time would come in, and it is difficult to answer a question like this without knowing all of the conditions. I do know that the British chemical and physical requirements are more exacting than ours. You might say that it is very simple to take the French plans and specifications for a 75 and build the gun, but when you come to think that their plans and specifications are all laid out on the metric system, and all the standards and sizes and everything that goes into it differ from our standards, it introduces a lot of complications; and then there is so much more hand work in their shop methods over there. There is nothing like the tendency to rely on jig work. So it is a much more difficult task than it would seem.

The French specifications were a bit lower than ours in regard to elastic limit and elongation. Here is an interesting point to show just how delicate this whole thing is: We made 155-mm. howitzers according to the French specifications. They are interchangeable, and we could set them on French carriages. We made

this gun on our own steel specifications, which are a good deal higher than the French. Our elastic limit requirements and our elongation and reduction requirements are higher. And yet some of those guns made on the French plans and according to our American requirements have been expanded at the muzzle in the proof firing. We are not sure what that is due to but it is probably due to the fact that our powder is more progressive than the French. French powder will develop its maximum pressure at an earlier stage in the explosion. The amount of energy which is delivered to the projectile when it leaves the gun is the same in both cases, but with our powder the muzzle pressure is higher and as a result some of these guns are expanded at the muzzle. I believe that is what caused the expansion, but I do not know. That illustrates how careful you have to be and you can not take other plans and apply them to your own conditions.

MR. G. D. CHAMBERLAIN: Are corrugated molds used?

MAJOR F. F. MCINTOSH: No, they are straight faced. On those that were corrugated, the dish in the side was very slight. You would hardly call it corrugation.

A MEMBER: Is there any high phosphorus specification?

MAJOR F. F. MCINTOSH: No. The English, I suppose as the result of the fact that they have very low phosphorus materials available, were more strict than the United States regarding phosphorus. That is largely a matter of national resources. I think the French specifications are about the same as ours, but I do not recall definitely. They were forced to the use of basic material later in the war and were making basic steel for cannon forgings. I think they were using 0.05 as the maximum in both phosphorus and sulphur. The French government relies largely on the physical test of the metal.

A MEMBER: I believe you stated that electric steel was not used for forgings. Was that an economic matter or a belief that the other steel was better adapted?

MAJOR F. F. MCINTOSH: I think it was more an economic matter. As far as I saw they were using the electric furnace to

melt up turnings and alloy scrap and things of that kind for shells and industrial steels.

A MEMBER: What is their practice in regard to steel making temperatures?

MAJOR F. F. MCINTOSH: Their pyrometer at one plant usually read 1475 to 1500 degrees C. in steel in the spout. Of course we know that was not correct, and I do not know what the true reading was. Most of the melters over there said, get it as hot as you can. And the fact that they teem through such a small orifice as ½, ¾ and ⅞ inch is the best indication of the temperature.

A MEMBER: Do they hold the steel right along in the ladles?

MAJOR F. F. MCINTOSH: No. They start to teem as soon as the heat is in the ladle. They start with very hot steel and get no skull in the ladle; but if you look into the molds when they are teeming, due to the fact that they use a small nozzle and the steel runs in slowly, you will see the surface of the steel is more or less breaking all the time—a result such as we get with a fairly cold steel and rapid teeming. I think the slow teeming into the mold means that though they start with very hot steel in the ladle they get the same effect as if they started with cooler steel and used a larger nozzle, as far as the temperature in the mold is concerned.

MR. PHILO KEMERY:* Pouring a 50- or 60-ton heat through that nozzle would mean 40 minutes. Does it take them that long?

MAJOR F. F. MCINTOSH: Yes. At one plant in Scotland they said they have had a heat in the ladle three hours without any trouble. Of course it always meant slow work and a long time in the ladle with a ¾- to ⅞-inch nozzle.

MR. GEORGE L. NORRIS:† Do they have any trouble with very large ingots rupturing?

MR. F. F. MCINTOSH: I did not see any indication of it in

*Metallurgical Engineer, National Tube Co., Pittsburgh.
†Metallurgical Engineer, American Vanadium Co., Pittsburgh.

the scrap pile or around the works, and judging from all they told me they had no particular trouble.

Mr. George L. Norris: That is one of the causes of flakes.

Major F. F. McIntosh: Well, I don't know. There is very good evidence that flakes are internal ruptures; but, on the other hand, when we get these small ones, one of the characteristics of the metal is that the effect on the tensile strength test will be indicated by a low reduction and elongation, and yet the tensile strength and elastic limit will be high. Look at the fracture, and that flake is 10 or 15 per cent. of the area. If it is a rupture how could you get the elastic and tensile strength with that much of an actual tear?

Mr. George L. Norris: I recently saw a transverse slice, from a large fluted or corrugated gun ingot, that showed ruptures of the primary crystals, about four to six inches in from the apex of each corrugation. The ingot was forged into a round about one-third the sectional area, and a slice from this on etching showed the ruptures very distinctly, although the forging had closed them up so they were not apparent except by etching.

I have examined broken test pieces from gun forgings that showed a flake on the fracture. These test specimens, when split lengthwise and etched, showed several transverse ruptures, even in the threaded or unstrained end of the specimens. These ruptures had the same characteristics as those in the ingot referred to.

Major F. F. McIntosh: Those are very interesting things and, as one of my duties is to try to collect and sift out evidence on subjects of this kind, I will appreciate it if anyone having information of that kind will bring it to my attention.

A Member: There is another snowflake in nickel-chrome that is quite different from gun snowflakes. Those flakes are true crystal facets—polyhedral crystals. These I think are the most puzzling of all.

Major F. F. McIntosh: I knew the aircraft people had a lot of trouble with this defect and I hope some time to find out what their experience was.

A MEMBER: The principal thing that I find they are doing is simply to use greater care in melting and pouring—not trying to get two tons of steel where they should normally get one ton.

MAJOR F. F. MCINTOSH: All the evidence seems to point that way. If you make your steel right you will not have trouble with it and if you do not make it right you are very apt to have trouble. That is, steel not made with the greatest care is more subject to these defects than well made steel. Some people believe it is the result of too rapid heating and quenching; others that it is the result of forging. But I think they will all agree that with steel that is made first class to begin with you can cast it or forge it or heat it with a great deal of latitude and not get these troubles.

A MEMBER: Some of the metallurgists of this country came to the conclusion that finishing the steel and pouring it too hot was responsible for flakes. That is quite contrary to the English practice.

MAJOR F. F. MCINTOSH: One may be a well made steel and the other a steel that is not properly made. An improper material cast at a high temperature may cause trouble. I hope to do what I can to find out what this defect actually is and whether it is a segregation of the nickel and cobalt, etc., as certain evidence is claimed to indicate. It seems to me that the whole thing is a challenge to science, to take this admitted defect and tell what it is. Every time I see a piece of steel containing the so-called flakes, I feel just as if some person whom I disliked very much was sitting there sticking his tongue out at me. Here is a piece of metal, known to contain an enemy. We know where he is but we have not captured him and found out what he is. He is an insulting challenge to the metallurgist.

MR. PHILO KEMERY: How much time do they take to make that 80-ton heat?

MAJOR F. F. MCINTOSH: As I recall, about 14 hours.

MR. G. P. MCNIFF:* What is the shape of the test pieces used in that impact test?

*Metallurgical Engineer, National Tube Co., Pittsburgh.

Major F. F. McIntosh: The English use a square one. The English aircraft people have developed a round one. The reason the munitions people stick to the square one is that they are accustomed to it and know how to interpret it and they do not want to adopt something new in an emergency. But I talked with several people who were responsible for such things in the British munitions board and I do not believe there is any doubt that after the war the manufacturers of munitions in Great Britain are going to have to meet the impact test as a routine test. It is a transverse test; it is not longitudinal; it is tangential to the circumference. They cut the disk off and lay out on it the two "benders," two tensile and also, under new requirements, two impacts. With the Izod test they can get three impact tests from one test piece.

Mr. G. P. McNiff: On the question of reduction of area I would like to ask whether they have arrived at a minimum amount of reduction to get good results.

Major F. F. McIntosh: I do not believe they have.

A Member: Is there any tendency toward making a cast gun in France or England?

Major F. F. McIntosh: No, there is no tendency that way. One or two very experienced men in our Ordnance Department have said that if you could be sure you had sound material they thought it was a possibility, but they were afraid of the casting. There is some very interesting work coming out in the next few months which has been done by the United States Bureau of Standards in regard to testing the soundness of metals. It has been used very satisfactorily in certain industrial testing, locating not only blow-holes and pipes but segregations.

This has been done also to a limited extent by the X-ray, but the penetration of the X-ray limits that to only a thin section, perhaps half an inch as a maximum. The other test is a magnetic one, which has greater possibilities.

NECROLOGY

Bliss, Homer N.	Langley, John W.
Ernst, Alfred	Laub, Hermann
Escoreal, Andres	Leland, Ralph M.
Harlow, James H.	Overmeyer, Walter S.
Henderson, J. W.	Picton, C. F.
Kent, William	Reed, Jean B.
Kidd, Walter Scott	Stevenson, John D.

Turner, W. V.

James H. Harlow

Westminster, Worcester Co., Mass., Sept. 30. 1846.
Darlington, Md., October 6, 1918.
Charter Member, January, 1880.
Secretary, 1880-1884 and 1891.

On October 6, 1918, at his home in Darlington, Maryland, occurred the death of Mr. James H. Harlow, at the age of 72 years.

He was born September 30, 1846, in Westminster, Worcester County, Mass. He was of distinguished ancestry, three of his ancestors having come over on the Mayflower—John Alden, Priscilla Mullens and Governor Bradford. As a boy he was not strong and he went to school but little, being taught at home by his mother. At the age of 17 he became an apprentice in a small machine shop in Leominster, Mass. His knowledge of mathematics and engineering he acquired largely by private study and while assisting his father, who was a civil engineer, in his engineering work. In 1864 he was employed in the office of Proprietors of the Locks & Canals, Lowell, Mass. From 1865 to 1867 he was employed by the water-power company at Lewiston, Maine. Then for about three years he was in Davenport, Iowa, engaged in the improvement of the channel in the Mississippi river near Rock Island, Ill., and also on a railroad survey. In 1871 he returned to Lowell, Mass., and was Assistant Engineer in charge of laying the pipe lines in the original plant of the

Lowell water-works. About 1873 he went to Pittsburgh, and was Assistant Engineer in the building of the *new* water-works at Pittsburgh. About a year later he opened an engineering office in Boston, and later he was employed by the Metropolitan Water Supply Commission. In 1877 or 1878 he returned to Pittsburgh and, as Chief Assistant Engineer under Capt. Mahan, built the lock walls and put in the foundation of the Davis Island Dam on the Ohio River. In 1880 he opened an office in Pittsburgh for general engineering work. He was Chief Engineer of the Monongahela Navigation Company from 1881 to 1887, during which time he built the lock at Dam No. 7 on the Monongahela River and the second lock at Dam No. 3. In 1881 he organized the New Castle Water Company, New Castle, Pa., and built the water-works. In 1885 he organized the Water & Gas Works Construction Company which built water-works plants in Wisconsin, Indiana, Illinois, Ohio and Pennsylvania, and laid the 30-inch gas main for the Philadelphia Company, extending from Fifth Avenue Extension along Frankstown, Penn and Liberty Avenues to Tenth Street, Pittsburgh. In 1887, with his brothers, Edward J. and George H. Harlow, he organized the firm of James H. Harlow & Company, which did a general engineering business and built a number of water-works plants and sewerage systems, and also did some street paving. In 1888 he obtained the charter of the Pennsylvania Water Company, and in that and the following year built its plant. He continued as President of that Company until 1902 when he sold his interest and moved to Maryland. He had, for a number of years prior to that time, been interested in the development of the water-power of the lower Susquehanna River. After moving to Maryland, he was connected with various engineering and other enterprises, chief of which was the Susquehanna Power Company which controls the power of the Susquehanna River from the dam of the Pennsylvania Water & Power Company at Holtswood, Pa., to tide-water. At the time of his death he was Vice President and Chief Engineer of that Company, and of the Bel Air Electric Company. He was also director of the Baltimore County Water & Electric Company, and Treasurer of the Havre de Grace Electric Company. In addition to his professional and business interests, Mr. Harlow always

took an active part in the religious and civic affairs of the community in which he lived.

Mr. Harlow was a charter member of the Engineers' Society of Western Pennsylvania and was its first secretary, serving from 1880 to 1884, and again for the year 1891. He retained an active interest in the Society until he left Pittsburgh. He presented one paper before the Society and took part in numerous discussions of papers presented by others. His wide experience as a designing engineer, as contractor and as operator of utilities had given him a fund of information which always secured for him a respectful and interested hearing. He was a member of the American Society of Civil Engineers and various other technical societies, including the Pennsylvania Water Works Association, of which he was one of the organizers, served for several years on its Executive Committee and was at one time its President.

Joseph Wesley Henderson

Canada, February 22, 1869.
Pittsburgh, December 19, 1918.
Joined the Society, September, 1905.

Joseph Wesley Henderson died at the St. Francis Hospital, Pittsburgh, December 19, 1918, of pneumonia, after a very brief illness.

He was born in Canada, February 22, 1869, and was brought to the United States when he was about three months old. His education was commenced in the public school of Jackson, Michigan, but did not end with his school days, for during his whole life he was a close student of not only technical matters, but also every branch of human affairs. When still in his 'teens, having a keen desire to see something of the world, he took a trip to Australia, and when about 20 years of age, went with the Illinois Steel Company, South Chicago, where he spent four or five years in the chemical laboratory. In 1895, he left the Steel Company to enter the laboratory of the Griffin Wheel Company of Chicago, and later to get a still broader experience, entered the Foundry Department of the same Company. In 1900, he went

with the Maryland Car Wheel Company to take charge of the plant at Baltimore, Md., and in 1904 came to Pittsburgh to become superintendent of the Central Car Wheel Company, McKeesport, Pa., and while in this position his successful methods attracted the attention of the President of the Standard Steel Car Company, who commissioned Mr. Henderson to design and build the Butler Car Wheel Company's plant at Butler, Pa. He was Works Manager of the Butler Plant until the spring of 1907, when he with Henry Gulick, formed the Gulick-Henderson Company. In 1914, prominent men of affairs and public officials of Pittsburgh believed the time was right to make a united effort to make the City of Pittsburgh a cleaner city which they believed could be successfully done by placing at the head of the department a technical man and to this end Mayor Armstrong appointed Mr. Henderson as chief of the Bureau for Smoke Regulation, which position Mr. Henderson held at the time of his death.

From the great success made by Mr. Henderson in this Department, he became widely known throughout the country and received many requests to give public lectures on the subject of smoke regulation. Mr. Henderson was a member of the Engineers' Society of Western Pennsylvania, American Society of Mechanical Engineers, American Institute of Mining Engineers, Chamber of Commerce of Pittsburgh, Pittsburgh Athletic Association, and Syria Temple Crescent Lodge F. & A. M.

Mr. Henderson is survived by his wife, Clara C. Henderson of Pittsburgh; and his mother, Mrs. Margaret McKinley Henderson; his one brother, Dr. Wm. C. Henderson; and his sister, Mrs. Stokes—all of Battle Creek, Michigan.

William Kent

Philadelphia, March 5, 1851.
Gananoque, Ont., September 18, 1918.
Charter Member, 1880.
First Treasurer, 1880.

William Kent of Montclair, N. J., one of the charter members and the first Treasurer of this Society, died at Gananoque, Ontario, on September 18, 1918. Mr. Kent was born in Philadelphia on

March 5, 1851. He attended the public schools of that city, and later attended night classes of the Cooper Union for a period of five years. He engaged in work at the blast-furnace of Cooper, Hewitt and Company, Ringwood, N. J., where he remained until 1874. He then entered Stevens Institute of Technology as a special student, finally entering the class which graduated in 1876, when he received the degree of M. E. During his senior year he assisted Dr. R. H. Thurston in the investigations he made for the Government in testing iron, steel and alloy metals.

From 1877 to 1879 he was editor of the *American Manufacturer and Iron World,* of Pittsburgh, and in 1880 he became connected with the Shoenberger Steel Company in the open-hearth department. It was during this period that he assisted in the founding of this Society.

After leaving the steel business, Mr. Kent served for a time with the Babcock & Wilcox Boiler Company, and in 1887 became general manager of the Spring Torsion Balance Scale Company.

In 1891 he began to practice as consulting engineer, and in 1895 became associate editor of the *Engineering News*, in which work he continued until 1903, at which time he accepted the position of Dean of Mechanical Engineering in the L. C. Smith College of Applied Science in Syracuse University. In 1908 he became general manager of the Sandusky Foundry and Machine Company, Sandusky, Ohio, and in 1910 he resumed his consulting engineering practice.

Mr. Kent was best known as the author of Kent's "Mechanical Engineers' Pocket-Book," which by 1916 had reached its ninth edition. He was also the author of "Steam-Boiler Economy," "Investigating an Industry," "Bookkeeping and Cost Accounting for Factories," as well as a large number of papers contributed to engineering societies, of which he was a member, and articles for various technical periodicals.

He did a great deal of work in connection with the classification of coals of the United States, and in the improvement of boiler efficiency, and in this line was regarded as one of the leading authorities of this country. He had also given special study to the science of shop management, and was a very earnest advocate of the use of the Taylor system of scientific management. In

addition he made a number of inventions, having taken out more than 20 patents.

Mr. Kent was an active member of a number of engineering and technical societies, having also served in an official capacity in several. Among the societies of which he was a member are the following: The American Institute of Mining Engineers; American Association for the Advancement of Science; Engineers' Society of Western Pennsylvania; American Society of Mechanical Engineers; American Society of Heating and Ventilating Engineers; Society for the Promotion of Engineering Education, etc. He was a man of very versatile abilities, an original thinker and good speaker; a thoroughly good engineer with a keen appreciation of the importance of facts in making all engineering decisions, and an abhorrence of any kind of technical information which was not supported by good reliable data. It was these characteristics which caused him to make clippings of various kinds of engineering data for a number of years, thus laying the foundation for what became in later years the Mechanical Engineers' Pocket-Book, and which appeared at a time when there was a great need for such a hand-book. In addition to these special fields of work, he took active interest in the whole broad field of mechanical engineering, as is evidenced by his writings, and by his memberships in the various technical societies. He is survived by his wife, one daughter, and two sons—Robert Thurston Kent and Lieut. Edward R. Kent, U. S. A., both engineers.

John Williams Langley

Boston, Mass., October 21, 1841.
Ann Arbor, Mich., May 10, 1918.
Honorary Member, May, 1893.
Joined the Society, November, 1888.

John Williams Langley was born in Boston, Mass., October 21, 1841. His father was Samuel Langley, a wholesale merchant of Boston, and his mother was Mary Sumner Williams of Marblehead, Mass. The Waite and Pierpont Morgan families, prom-

inent in early New England activities, were related to his grandfather and great grandfather on his mother's side.

He graduated from the Scientific Department of Harvard University as a chemist in 1861 at the age of 19.

Shortly after leaving school, was engaged as chemist and engineer in works for the reduction of copper, silver, lead and gold. Later acted as Assistant Professor of Physics in the United States Naval Academy at Annapolis, Maryland. Then Professor of Chemistry and Metallurgy in the Western University of Pennsylvania, Pittsburgh, where he was in close relation with the steel business and with steel manufacturers. He accepted the office of Professor of Chemistry, Physics and Metallurgy in the University of Michigan, which position he held for 14 years, from which he resigned to act as chemist and metallurgical engineer for the Crescent Steel Works of Pittsburgh, having in charge the department of the works making Bessemer and open-hearth steel. He left Pittsburgh to accept a position as Professor of Electrical Engineering in the Case School of Applied Science, of Cleveland.

Since 1870, in addition to the duties indicated above, he acted as consulting chemist and metallurgist for several steel firms and visited Europe to investigate and report on the condition of the Bessemer process for making steel.

In 1888 and 1889 he organized what has been known as "The International Committee for Standards of Analysis of Iron and Steel," securing the co-operation of prominent metallurgists in Sweden and France, and in England the British Association for the Advancement of Science and in this country, representatives of the University of Michigan and the American Society of Civil Engineers, New York.

On September 3, 1862, he enlisted and was stationed for a short period at the Charleston Navy Yard as examining surgeon and, for a year and a half, acting surgeon in charge of the U. S. gunboat "Pampera" stationed as guard ship at the mouth of the Mississippi River. He was discharged from the service September 1, 1864.

In 1877 he had conferred upon him by the University of Michigan, the honorary degree of M. D., and in 1902 that of Ph.D.

He became a Corresponding Member of the British Association for the Advancement of Science, in 1887, and an Honorary Member of the Engineers' Society of Western Pennsylvania in 1888 and of the New York Academy of Science. He was also a Fellow of the American Association for the Advancement of Science and of the American Institute of Mining Engineers.

He presented a great many interesting papers before the various technical societies. During the later years of his retirement, he remounted the eight-inch reflector that he and his brother made and as nothing remained but the figured disk, he made all other parts, consisting of the wooden tripod with limited altitude and azimuth adjustments and several eye-pieces of different powers, with their connections.

He also wrote several charming semi-fairy stories for children and usually gave a children's party twice a year.

He is survived by his wife and three children, Mrs. Mary L. Herrick and Samuel P. Langley of Ann Arbor and Mrs. Martica I. Whitman, wife of Paul S. Whitman, Engineer for the Riter-Conley Company, Pittsburgh.

Hermann Laub

Durmentingen, Germany, April 14, 1855.
Pittsburgh, December 10, 1918.
Joined the Society, May, 1902.

Hermann Laub was born in Durmentingen, near Riedlingen, Wurttemberg, Germany, on April 14, 1855. He studied Civil Engineering at the Technical High Schools of Stuttgart and Munich. After serving a year in the Army he came to the United States in 1880, spent some time in New York and Denver, Col., and then went to Mexico, where he accepted a position with the Mexican National Railroad. He remained there three years, and during that time he built over 500 miles of railroad. During a visit in his native country in 1884, Mr. Laub became engaged to Miss Rosa Hauber. They were married in November, 1884. His first position in Pittsburgh was with Schultz Bridge Co., of McKees Rocks. Later he became associated with Gustav Lindenthal,

the now famous bridge builder, who in the eighties had his office in Pittsburgh. During that time Lindenthal and Laub built an extension to the Smithfield Street Bridge, and a bridge at Duquesne. After Lindenthal went to New York, about 1888, Mr. Laub continued the business up to the time of his death, and a number of large bridges, glass and steel works are monuments to his ability. Among others he constructed the bridge over the Allegheny river near Highland Park, over the Youghiogheny at McKeesport-Portvue, bridges at Brownsville, Pa., Parkersburg, W. Va., and the last one, which was finished shortly before his death, at Norfolk, Va. For the state of Pennsylvania he constructed about twenty bridges of various sizes. Work which probably required more skill than new construction was the replacing and strengthening of the Twenty-second Street bridge and the rebuilding of part of the Homoeopathic Hospital when it threatened to collapse while in course of construction, through failure of the foundations.

Hermann Laub's death came unexpectedly to his many friends and even to his immediate family. Although he had been ailing for several weeks, he seemed to be on the road to recovery. His sudden death means a great loss to his friends and his profession. A giant in stature, he had a genial disposition and upright character. He was a great lover of music and an excellent billiard player.

He joined the American Society of Civil Engineers in 1897 and the Engineers' Society of Western Pennsylvania in 1902. He was one of the founders of the Technischer Verein and of the German Club and held the office of President in both organizations.

Mr. Laub is survived by his widow, Mrs. Rosa Laub, *nee* Hauber, and four children—Mrs. Hilda Syme, Wilkes Barre, Pa.; Mrs. Rose Bates, Pittsburgh; Hermann Laub, Jr., Detroit; Gustav Laub, in the naval service—and several grandchildren.

GAS WARFARE AT THE FRONT

By Col. B. C. Goss*

When the United States entered the war, the use of chemicals had already reached a high stage of development and the importance of this branch of warfare continued to increase in both the enemy and Allied armies as rapidly as the necessary chemicals and means of projecting them could be developed.

A successful infantry attack was largely dependent upon the proper use of gas, thermit, and smoke, before and during an advance, and upon the ability of the opposing force to avoid casualties and to perform its functions in spite of the handicap of the gas. Rifles, machine-guns, and cannon were all rendered useless at the most critical times unless the men operating them were able to "carry on" in an atmosphere of gas. The choice of gases and of suitable targets, the proper time, duration, and rate of fire, and the co-ordination of the gas program with infantry, artillery, and other elements of the advance, became a science in itself; and on the staff of each unit commander, down to and including the battalion, there was an officer, or group of officers, who devoted the entire time to many problems of chemical warfare. These officers were called "Gas Officers" although their work was concerned with smoke, liquid fire, thermit, etc., in addition to "gas." The Gas Officers in the field were charged with the protection of our men against enemy gas, the supervision of the use of gas by our troops, the supply of a large number of items of gas protective material, and the collection of intelligence and material of enemy origin which might give information regarding new methods employed by the enemy.

Until the last few months of the war, our Gas Officers were chiefly concerned with protecting our men against enemy gas. Their work began, when their units were in the training areas

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behind the lines, with the issue of individual protective devices, drill in their use, and general education on the subject of gas warfare. Contrary to general opinion the gas mask, although absolutely necessary, was not the most important protection against gas. Even among the troops themselves, when inquiry was made regarding the preparedness of the unit to meet a gas attack, the answer was commonly given, "They are perfectly prepared; they can adjust their masks in six seconds." This same unit, on going into the line, would suffer very heavy casualties because the men were not educated on the subject of gas. Many never did get away from the idea that there was something mysterious about gas which followed no known laws.

This is well illustrated by an incident which occurred during the summer of 1918 at Regneville. The American sentry on guard at a front line post was new at the game and had received a great many instructions, which were not very clear in his mind, regarding the manner in which a gas attack could be recognized. At that time, a red rocket was being used as a signal to call for a barrage, and a green rocket was the signal for enemy gas. About 2:00 a. m., his nerves being "jumpy," he suddenly thought he saw or heard something moving in the wire in front of the trench. He reached for a supposed red rocket and sent it up as a call for a barrage. When it burst above him it was green. Looking up, and seeing the green light (the signal for gas), he dived into his carrying case, put on his respirator and sounded a Klaxon horn as a signal for everyone to adjust gas masks. The alarm spread over a large sector of the front.

False alarms were being given constantly, sometimes because a sentry smelled the fumes from a high-explosive shell and sometimes because of a dead rat.

The men must be taught all the enemy methods of use of gas and how each can be recognized—the sheet of flame and loud explosion indicating a projector discharge, the hissing sound denoting the escape of gas from cylinders, and the swishing whistle of gas shell, followed by a low burst with a peculiar ringing tone. They must know the odors of the important gases used, especially of mustard gas, and must be familiar with all the means of giving

the alarm, must know how to clear trenches and dugouts of gas, and how to take care of and inspect all the forms of gas defensive material.

Certain kinds of ground and certain kinds of weather are particularly favorable for enemy gas attack. The direction of the wind must always be observed in order that the men may know which way to move to get out of the gas atmosphere.

It is particularly necessary that every man should be able to perform his specialty without the loss of efficiency while wearing a gas mask. The artilleryman and machine-gunner must learn to fire a barrage; the runner to carry his messages; the lorry driver to control his machine; the officer to give orders; and the telephone or buzzer operator to use his instruments, while wearing the gas mask. All of these require continuous practice in order to develop endurance, for the first time the respirator is worn, it is almost impossible to keep it on for longer than fifteen to twenty minutes if doing any kind of work; in battle, as will appear later, it was often necessary to wear them continuously for eight or nine hours.

When a unit goes into the line the Gas Officer becomes a trouble hunter. Any area that is being shelled by the enemy requires investigating to see if gas is present and to see that men are wearing respirators in the places where the concentration is dangerous; that gas-proof doors are all lowered in the dugouts; that the proper care is given to gassed men. If mustard gas has been used, it may be necessary to evacuate the spot entirely until the chemical in the ground has been destroyed by a disinfecting squad. Trenches and dugouts are cleared by means of fans and fires. The Gas Officer and his non-commissioned officers must identify the gas which has been used and, unless they are absolutely sure that it is an old and well-known gas, shell fragments, unexploded shells, earth samples or specimens of contaminated water must be found which will serve to identify the chemical which has been used. A delay of a few days in detecting a new gas or gas mixture, and in providing protection against it, might result in the loss of thousands of lives.

When not actually concerned with enemy gas attacks, the Gas Officer must be continually making the rounds of the troops in

the front and reserve lines, inspecting the condition of gas defenses and seeing that the proper gas discipline is being enforced. Within two miles of our front lines, and at active battery positions, the respirator must be carried at all times in the "alert" position; that is, fastened firmly upon the chest so that the face piece may be instantly adjusted at the slightest warning. Behind this line, which was marked out on all prominent approaches by "Gas Alert Zone" signs, was another zone called the "Gas Danger Zone" which extended back 10 miles farther, inside of which everyone was required to carry a gas mask slung upon his person at all times. The alarms must be tested to be sure that they are always in working order, dugout blankets must be kept always moist, wind vanes must be kept in order, and stores of fuel must be provided for clearing of gas from dugouts. In the front lines gas masks must be inspected thoroughly every day, since a defective valve or minute hole, a cracked eye-piece or a wet canister might cause death at any time.

The one most dangerous method employed by the enemy for making a gas attack, was by means of so-called "projectors" or gas mines. Long rows of smooth-bore steel tubes were dug into the ground behind the enemy lines, usually three to five hundred yards to the rear of his front line trench. These might number anywhere from two hundred to two thousand or more. In each was placed a propelling charge and, on top of it, a bomb containing about 16 pounds of gas in liquid form, all of these tubes being connected electrically so that they could be fired at the same instant on to a village or group of dugouts occupied by our troops. These cylinders were placed at night and then concealed by camouflage and left for a period of days until a night came when the wind was favorable; that is, blowing towards our lines and with a low velocity. They were usually fired at some time in the early morning between 2:00 a. m. and daybreak when men were most likely to be sleepy and off their guard. A sheet of flame flashed behind the enemy lines, a heavy explosion was heard a few seconds later, and hundreds of these bombs came down all at once, like a flock of huge birds, on the woods or village where our men were, producing such a concentration that a single breath meant death. These bombs were filled with

phosgene, a mixture of phosgene and chlorpicrin, or a mixture of high explosive and diphenylchlorarsine. The only warning was the flash and explosion, after which the men had about 15 seconds, while the bombs were in the air, to adjust their respirators completely. If the sentry was not on the alert, if a man was not awakened quickly by the alarm, or if a respirator had been misplaced in the darkness, there was little chance of escape. To make this form of attack more effective the enemy attempted to fire these projectors from behind the brow of a hill so as to conceal the flash of discharge. The best means of protection against gas projector attacks, in addition to skill in adjustment of respirators and in recognizing the discharge of projectors, was in the location and destruction of the position by our artillery before the enemy had a chance to fire the bombs. This was done partly by following the movements of the enemy special gas companies, by means of prisoners' statements, by sounds of hammering on metal which usually accompanied the preparation of a projector emplacement and by aeroplane photographs of the area under suspicion. Whenever the Gas Officer received any indication of an impending projector attack, all units within range were warned to be on the alert, especially if the wind was in a dangerous quarter.

The first projector attack against American troops occurred on February 25, 1918, in the Bois de Remieres which was just behind our front lines in the Seicheprey sector and was held by a part of the First Eighteenth Infantry. About five hundred bombs were fired at 1:40 a. m. Some of the men were not awakened in time, some lost their heads when they saw the flash and heard the heavy explosion. There were 11 deaths and 88 casualties from this attack.

The most common form of gas attack was by means of artillery shell. Front lines, communicating trenches, groups of dugouts, cross-roads, and camps and villages, as far back as 10 miles behind our line, were subjected to this form of attack. Most of the gas, however, was thrown into the area extending back two miles behind the line and this was our "Gas Alert Zone." The enemy never fired a few shells at a time, except against inexperienced troops, in order to lead them to think that gas was

not dangerous. Usually at least two hundred shell were fired, if the target was a small one, and on important targets, such as woods occupied by our troops, they often fired two to three thousand shell. When they were using poison gas for this attack, as many enemy batteries as possible were concentrated on the target so that a high concentration of gas would be produced in the least possible time. The gas most used for this purpose, since we entered the war, was Green Cross 1, a mixture of diphosgene and chlorpicrin. Yellow Cross, or mustard gas, was the most effective of chemicals used in artillery shell and caused more casualties than all of the others together. The shell contains a liquid which is not very volatile and, when the shell bursts, only a small part of the contents becomes gas at once. The remainder is spread over the ground as a liquid which continues to give off vapor slowly for several days. The reason that mustard gas was so dangerous was because it did not have a very pronounced smell and because it had no immediate effect. As a result, unless a Gas Officer was present, the men often took off their masks within an hour after the bombardment had ceased and remained in the gassed area unconscious of any danger. Several hours later the gas took effect. The eyes became red and swollen, often to the extent of producing temporary blindness. Vomiting occurred and irritation of the skin began to be felt. The mustard-gas vapor condensing on the clothing passed through and produced severe blisters, particularly under the arms and between the legs, which often required months to heal. Death, when it occured, usually followed three days to a week or more after exposure, coming as a result of a secondary infection. The percentage of deaths from this gas usually did not exceed one to two per cent. of the total casualties but mustard gas was of great military value because the casualties were lost to their units for a period of from one to two months. It was impossible for men to wear respirators continuously for as long a time as this gas remained dangerous and, in order to avoid casualties, the ground had to be evacuated, or a relief provided for the men who had to stay in the gassed area in case the military situation made evacuation impossible. If a man wanted to go safely into an area shelled by mustard gas, he had to wear not only a respira-

tor, but a suit of special oiled cloth covering his entire body. If it was desirable to re-occupy the shelled area immediately, a disinfecting squad, armed with shovels and chlorid of lime, under the direction of the unit Gas Officer, was sent in to neutralize the mustard gas remaining in the ground.

A third common gas used was Blue Cross, an arsenic compound. This was used, mixed with high explosive, in almost every bombardment during the summer of 1918 preceding any enemy raid or attack. A bottle of this chemical was placed in the shell, as a solid, embedded in high explosive, so that the shell could not be distinguished from the ordinary high explosive by the burst. This gas was effective only when the shell burst very close to the men exposed, in which case it caused a very violent pain in the throat and lungs and a feeling of suffocation followed by violent cramps in the stomach. In small quantities, it produced sneezing, and this was the main purpose for which it was used by the enemy, since it made it difficult for our men to keep their respirators adjusted when forced to sneeze. The sneezing gas was always followed by a poison gas. Other shell were used in smaller quantities: Yellow Cross 1, Green Cross, Green Cross 2, Double Yellow Cross and Double Green Cross. One of the most important and dangerous parts of a Gas Officer's work was the collection of "duds," or unexploded enemy shells which were conveyed to division headquarters and thence to corps headquarters where the fuse was removed and a hole drilled in the shell allowing the poison gas to escape for examination. Unless sure of its composition a sample was sent to the Chemical Warfare Service Laboratory for analysis.

On the offensive side the Gas Officers assisted the infantry, artillery and gas troops in the use of chemical weapons, including gas, liquid fire and smoke. The unit Gas Officer knew his own sector better than any one else and knew what enemy positions opposite were most strongly held. He advised and helped in the formation of smoke barrages over enemy positions to screen the movement of our troops; in the reduction of machine-gun nests by means of liquid-fire rifle grenades or thermit bombs; in

driving the nemy out of dugouts by means of gas grenades or in making large-scale gas attacks by projectors, Stokes mortars, or artillery.

Between Thiaucourt and Metz, and behind the German lines as they existed November 10, 1918, was a heavily wooded plateau. This plateau was opposite the front of the Second American Army, and it was very strongly protected by enemy concrete "pill-boxes," or concrete huts for machine-gun emplacements. Judging from the results when any one tried to move along that part of the line, there were several Boches in each of those "pill-boxes" and each one must have had several machine-guns. At any rate, it was determined that, before an attack which was to take place on the front of the whole Second Army on November 12, the number of Germans in this plateau should be reduced, and we had made all preparations for accomplishing this. We had four companies of British gas troops that had been attached to the Second Army, and plans had been made for an attack with the so-called "gas projectors" on this plateau.

Early on the morning of November 11, orders were received at Army Headquarters that at 11 o'clock that morning all hostilities should cease. We had to cancel the proposed gas attack. I thought at the time that I had made my last gas attack, but events have proved that that was the greatest mistake I ever made, for I have done nothing else since.

Even our own army does not begin to realize the part gas played in the war. It will probably be a long time before any of us do. Most of us think of gas as a mean of killing men—a means of inflicting casualties upon the enemy. It is that, and it is a tremendously important weapon for that purpose—one of the most important developed during the war. During the months of May and June the First Corps was averaging 3000 casualties a month from gas alone. The British Army lost something like 180 000 men from gas during the period from July 1916, when the Germans first began using gas shell, until the end of the war. But in spite of these terrific losses, gas is much more important as a tactical weapon than as a means of producing casualties. By this, I mean that its real importance is as a method of advancing our own infantry or preventing the advance

of the enemy. In the latter days of the war it had reached such a stage of development that few movements of any kind were made without gas and smoke and fire, and the use of these things in connection with infantry operations had become a science in itself. If you are going to make an attack, it is necessary to consider what you are going to do to the enemy's front line, what you will do to his reserve lines, what you will do to the front lines on the flanks of the sector to be attacked, what you will do to the batteries protecting him, his cross-roads and lines of communication. Every one of these would call for a different chemical projectile if it were available. We never had a choice of chemicals or projectiles so that we could use them in this way. It is not generally realized that machine-guns, rifles, artillery and other means of defense all become worthless unless the men are able to use them in an atmosphere of gas in a critical time. It is this tactical importance of gas that is going to make it one of the most important things in any future war.

Let us go back to the spring of 1918 when the Germans drove against Amiens in March. I doubt if you know the part gas took in that attack. I was with the British Third Army at that time. In the front of that Army, which was only a part of the entire front of attack, the Germans fired something over 250 000 shell in three days. Their tactics were to fire these shell, mostly mustard gas, from about 11 o'clock at night until midnight. Then they stopped, and started along toward daybreak and shelled for about an hour again. The result of this was that the whole sector was flooded with gas almost continuously. The Third Army suffered 4800 casualties including 550 officers.

But that was not the most important result. The men who were not gassed were so exhausted with wearing respirators over that long period of time that many of them were unable to make any effective resistance when the attack came. The effect of wearing the old type of gas mask was tremendous. After you had it on half an hour, gripping the mouthpiece between your teeth, you would just as soon die as wear it even a few minutes longer. The elastic bands on the head caused headache and gripping that rubber mouthpiece between the teeth was almost unbearable, but the men were compelled to wear their masks for eight or nine

hours at a stretch, each day for a period of three days preceding the attack. The same thing happened when the enemy attacked in the direction of Mt. Kimmel. They passed Armentieres on both sides. The British Army was drenched with mustard gas and the attack succeeded.

Gas, from the standpoint of those who use it at the front, is considered as belonging to two big classes, and all gases may be roughly divided into these two classes. One class is called "neutralizing" gas, and such gas is not intended to kill. It may act in any one of a number of different ways, causing temporary blindness, choking, irritation of the throat and lungs, or sneezing. It is used for the purpose of getting what we call military neutralization. If there is an area where we want to prevent the enemy from concentrating in preparation for making a counter-attack we would use such a gas. Immediately you have defined the purpose, you have defined the way in which you use it and the necessary properties of the chemical. It must be something that lasts a long time, and must be in such concentration that it necessitates the wearing of a respirator. Such shell would be fired slowly and scattered over the area. The other class we call "lethal" gas, and for that we would choose a gas producing casualties and death. These would be fired as rapidly as possible, putting the greatest number of projectiles possible on the target in the least possible time. The object is to get concentration, but with a chemical that does not last very long; because usually troops must be sent over, following the gas attack. Some lethal gases may be followed in 20 minutes, others in an hour, or two or three hours, depending on the tactical use.

I am firmly convinced that if the Germans had had mustard gas our St. Mihiel and Argonne attacks would have been a failure. We gave them every opportunity to defend their positions with gas. They had used up their supply of mustard gas at the same time they used up their reserves in the series of spring offensives. After the St. Mihiel attack, in which we fully expected quantities

of mustard gas to be fired on us, we found German orders in captured dugouts, absolutely prohibiting the use of mustard gas except on orders from army headquarters, and we found no mustard gas in their dumps. It developed after the armistice that they had used only the old chlorohydrin method for making mustard gas, which is very slow. The best spy Germany had was in France during October trying to find out how the French were making such quantities of mustard gas. They eventually found out, because they were using our method during October, but not in time to get mustard gas to repel these attacks. The Blue Cross shell was not generally effective. The reason was that the chemical was not sufficiently shattered by the explosion. The results were very serious right near the shell, but if a man was not killed he got over it in from five to seven hours.

We were very much afraid in the summer of 1918 that the enemy was going to find a new way of putting over that gas, and we knew our masks would not stop it.

The life of a Gas Officer, especially in the early days of our participation in the war, was a continuous struggle against both the enemy and lack of interest among our own men. No one realized the full importance of gas until he himself had been exposed. Men often used their mask carrying cases as a place to carry mess kits, knives, food, and all sorts of things, although this was strictly forbidden.

A story is told of a general who was on his way to a mask drill that he had ordered, when he discovered that he had forgotten to bring his own mask. Calling a private, the General borrowed his mask for a few minutes and went to the drill. Here he found a Captain who had forgotten his mask; the General reprimanded him for his carelessness and then said, "I don't believe you know how to put on a mask. Take mine and show me." The Gas Officer gave the signal by calling "Gas," whereupon the Captain dived into the carrying case and pulled out its sole contents—a pair of old socks.

Fig. 1. Bursting of a Gas Projectile Near American Battery in Action.

Fig. 2. Bursting of a Four-Inch Stokes Mortar Smoke Bomb.

Fig. 3. Beginning of a Smoke Screen Produced by Stokes Mortars.

Fig. 4. Adjusting a Gas Mask to Wounded Man.

Fig. 1–4 illustrate some of the incidents connected with gas warfare.

The work of the Gas Officers was dangerous and difficult and many were killed and wounded; they saved the lives of great numbers of our men and they deserve the credit of rendering to our Army, pioneer service of an unusual type.

MR. H. D. JAMES:* I wish to propose a vote of thanks to the speaker for his very interesting and very instructive address. This one, and Colonel Walker's on the production of the gas, give us a wonderfully good idea of gas warfare.

*Division Engineer, Westinghouse Electric & Manufacturing Co., Pittsburgh.

GAS, SMOKE, AND FLAME IN THIS WAR AND THE NEXT

By Col. William H. Walker*

It is just a year ago that the Germans were making their very successful drive toward Amiens, and the world was holding its breath to see whether they would eventually reach the channel ports, attack Paris, and overrun France. To-day the Allied armies stand astride the Rhine, and Germany is more or less beaten. That she could have been more thoroughly beaten everybody knows, but how badly she actually *is* beaten nobody knows.

I think it is worth while to consider some of the important factors which were effectual in winning the war, in order that we may determine what our policy should be in the future. Of course we all have great hopes that a League of Nations will make war very much less probable that it has been in the past; but, I take it, no one is so foolish as to think for a moment that, whatever the League of Nations may accomplish, it will relieve any nation of the necessity of providing for its own defense. Therefore, it becomes important to determine what we have learned in the recent war, and how we will plan our future.

When the Germans first launched their gas attack in 1915 it was thought extremely barbarous. The reason it appealed to us at that time as being barbarous was because it was so fatal. The troops of the Allies were not in any way prepared for the attack and it was, from that point of view, wonderfully successful.

The question arises, what is humane warfare? It seems paradoxical to talk about any warfare being humane. Broadly, whatever the cause or object of a war may be, the object of a battle is to destroy the enemy's forces. The completeness of that destruction determines to some extent whether the method be a barbarous or a humane one. One extreme is, killing the enemy;

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and that used to be the only way. You remember when the Children of Israel went out to war they destroyed the enemy completely—men, women and children. The other extreme is to take the enemy captive. This takes the man out of the battle line, but at the same time preserves his life and does not render him a cripple. Between these two extremes there are all degrees of casualty, starting with a very mild one, which takes a man out of the battle line for a few days; and extending to a casualty where a man is permanently crippled and no longer a part of the fighting force. It seems to me that we can say that that method of warfare is most humane which provides for taking the greatest number of prisoners with the smallest loss of life. Any method that incapacitates a man for the moment so that he may be taken prisoner, and yet does not render him a permanent cripple, is a humane method.

From this point of view, gas warfare, as it is turning out, is particularly humane. Statistics, as they are being accumulated from both the English and the American armies, show that more than 30 per cent. of the casualties of the past war were due to gas. That leaves 70 per cent. for machine-gun and rifle fire, shrapnel, and high explosives. Of this 30 per cent., between four and five per cent. were fatal. Of the other 70 per cent. of the casualties, between 20 and 25 per cent. resulted in death. Therefore, the total number of deaths resulting from the two methods of warfare is very much less with gas than with the other types of offensive. Furthermore, very few of the gas victims are permanently disabled.

At Base Hospital No. 7 in Baltimore, where they have a great many blind men returned from the other side, they state that all the gas cases will be very materially helped and none of them will be so severe that the men will be permanently blind. On the other hand, men who are blinded by high explosives are permanently blind. So we must revise our opinion a little in that respect. While I am not saying that men do not suffer terribly by gas poisoning, it is my opinion that the disability is not permanent and the number of permanent cripples is very much less in casualties from gas than in those from high explosives.

Just to trace for a moment the progress of warfare; we started, of course, when a man's ability to win was measured by his strength; but the shepherd boy, David, with a sling shot overcame Goliath, notwithstanding the splendid armor and the great strength of the latter. From that time on, men have been striving to perfect engines of war. The ingenuity of man has been devoted to making more efficient the destructive weapons available—to getting a rifle that would shoot farther and more accurately; a projectile that would penetrate more deeply; an explosive that would be more powerful.

When each of these new methods was introduced objection was made to it. Therefore, we need not be surprised that when the Germans introduced gas warfare the world pronounced it an inhuman method. However, in my opinion, it has come to stay, and we should make adequate provision for it. For example, the Chemical Warfare Service—the staff organization which is charged with the development of both offensive and defensive material for gas warfare—should be strongly supported, in order that we may keep well abreast of the times in the design, manufacture, and use of this type of munitions.

Along with gas, we have smoke, used for protective purposes. My own opinion is that in the next war we shall see this method of defense used under most diverse conditions. I think one of the greatest fields open to inventive work in offensive warfare lies in the ability to throw on the enemy material at a very high temperature.

When we entered the war in 1917 it had been in progress since 1914. Gas was first used in the spring of 1915, but the French and English, though they immediately began to plan a gas program, did not get into active operation until about Christmas of that year.

Just to get that matter before us, the first gas which was used was chlorin. This gas is very toxic, but it is not a good war gas because it is easy to protect against it. Phosgene, introduced early in the fall of 1915, is a combination of carbon monoxid and chlorin, which gives us a relatively simple molecule but one which is very highly toxic. In small concentration it has a delayed effect on the heart which frequently proves fatal.

The method of manufacture of phosgene employed by the Allies was one which had not been previously developed to any great extent.

The chlorin is made by passing an electric current through common salt. This has the effect of disintegrating the salt, and the chlorin passes over, leaving caustic soda.

The method of making carbon monoxid had never been developed on any large scale because it had never been necessary to make any large quantity of it. The method we used to get oxygen was first to liquefy air, and from that liquid allow the nitrogen to distil off, which it does at a temperature higher than oxygen, leaving the oxygen behind, and thus giving relatively pure oxygen. The French and English pass that oxygen up through a gas-producer filled with coke, and the oxygen unites with the carbon giving carbon monoxid. The difficulty with that method was that the heat generated was very great so that the life of the generators was short and therefore the expense was great. When we came to make carbon monoxid it was obvious that the amount we required was so large that it would be impossible to make it as it had been made in France, and another method was necessary. Our engineers conceived this idea. Carbon dioxid unites with carbon to give two molecules of carbon monoxid, and that reaction absorbs heat. It was a clever idea to provide the proper amount of carbon dioxid and oxygen so that the heat of generation in this reaction would be absorbed by the second. In that way a very definite temperature could be maintained and the production of carbon monoxid very greatly increased. The apparatus was designed on that basis, and when put into operation it ran beautifully and there was never a time when we were unable to obtain any amount of carbon monoxid we wished.

Phosgene, of course, is a gas. We could not ship or fill a shell with gas itself because we could not get very much in volume; therefore it must be liquefied, and it was fortunate that phosgene liquefies at eight degrees C. at atmospheric pressure. It is highly toxic and, when inhaled in any considerable quantity, death soon results. In small quantities it produces little immediate discomfort, but may cause death from delayed heart action.

The next gas which was used was chlorpicrin. The Germans did not make much of this because it was so expensive. The raw materials are picric acid, and chlorin in the shape of bleaching powder. Picric acid is very expensive to make because it requires so much sulphuric and nitric acid, and the reaction between bleaching powder and picric acid is very wasteful.

The greater part of natural gas is methane, which is one molecule of carbon and four of hydrogen. If we replace three of these hydrogen molecules with chlorin, we have chloroform, with which you are familiar. That is toxic only as it is an anesthetic. If we replace the hydrogen of chloroform with nitric acid, we get chlorpicrin—a very simple molecule which one would never predict would have the qualities which it has. The method of making it is very difficult because we have to have this very large picric acid molecule to break up the association. Chlorpicrin comes in between the lachrymators and those gases which are very strongly toxic. It is a lachrymator and at the same time it is toxic, and it is a vomiting gas, so-called. This chlorpicrin was used very largely by the English and also by the French; but when we got busy we were able to make it in comparatively large quantities and send it abroad in bulk. But the French and English had larger facilities for shell manufacture than they did for gas with which to fill the shell, and we furnished the gas. It was the first of the toxic gases to be made on a large scale in the United States for war purposes.

The lachrymators are tear-producing gases. They are not, as a rule, very toxic. They are very effective, however, because so small a concentration is capable of producing tears, and when the tears flow to such an extent that a man cannot see he is put out of commission. While it is a very simple matter to get a very high concentration of gas in a room, it is a very difficult thing to get a concentration out in the open. because the least current of air carries the gas away and it does not require a very high wind to sweep it beyond the zone of action. The lachrymators are particularly effective for rendering a battery inoperative.

The lachrymator which we made was one called brombenzyl cyanid. It was so effective that one part in 25 000 000 immediately produced such a violent flow of tears that the victims

could not see. Higher concentrations produce temporary, but not permanent, blindness.

The so-called sternutatory gases are those which produce violent sneezing. It does not seem a very harmful thing to make a man sneeze, but the Germans first used a material called diphenylchlorarsine which is a marvelous thing, in that the slightest portion makes a man sneeze so violently that he vomits, and throws off his mask. If there is a lethal gas present, a casualty results.

The other type of gas is represented by a material known as mustard gas but which, as a matter of fact, is not in any way related to mustard, and which, despite its common appellation, is not a gas, but a colorless or slightly yellow oily liquid. The crude material has a slight odor resembling mustard or garlic—hence the name. To the chemist it is known as dichlorethyl sulphid. The material is very simple in its chemical composition and is made by introducing ethylene into sulphur chlorid under definite temperature conditions. In itself, it is not a violent poison, and the vapors can be inhaled for an hour or so without great discomfort. Owing, however, to the violence with which the material attacks the mucous membrane, irritation is set up which results in symptoms closely akin to those of pneumonia. The vapors also affect the eyes, producing an intense irritation and temporary blindness. Contact with the skin at first causes a burning sensation which within a few hours produces a blister, and this in turn is followed by a deep running sore which heals only after six or eight weeks careful nursing.

Smoke-producing materials are used for protective clouds preceding an attack. The most important substance for this purpose is phosphorus, which it will be recalled burns readily in air with a great quantity of dense, white smoke. This smoke has a high obscuring power but is in itself not toxic. In addition to phosphorus, many shell were filled with a substance known as titanium chlorid which when atomized by the bursting of the shell produces also a very dense non-toxic smoke.

The flame-producing mechanisms were, on the whole, not very successful. Like most other things, success depends upon the unexpectedness of the attack. The first use of flame pro-

jectors—which was nothing more than a means of squirting burning oil into the trenches from reservoirs under pressure—was very effective. Subsequent attacks, however, failed because the operators could readily be shot down and the flame limited to a very narrow radius. Not long previous to the armistice, the American gas service in France had developed a very effective method of using phosphorus and thermit in trench mortar bombs. It is believed that had the war continued this method of clearing up machine-gun nests would have been rapidly developed and have proven of great value. The psychological effect produced upon troops by running down upon them molten iron and burning phosphorus is most pronounced and the Boche responded quickly to this treatment. I believe that one of the great developments in future warfare will be the application of very high temperatures, because protection from this form of attack is very difficult.

When the war broke out we were just as unprepared in this as we were in everything else, though we had had some men on the other side. Let me describe the standard methods by which this gas was thrown across. First, of course, came our so-called gas cylinders. The first gas cylinders used by the Germans were cylinders in which liquid chlorin had been held. When a large number of cylinders had been brought up in the trenches and were ready, they were all released at once, producing a great cloud of gas to float across to the enemy. That was the first gas attack, which was so effective. It is interesting to know that if the Germans had not been afraid to follow it up, there was absolutely nothing between them and Calais after that gas attack was pulled off. A good many of the Canadians and Turks were killed and had the Germans made a charge they could have gone right through to the Channel ports. As a matter of fact, they did not; they delayed until they could prepare, and failed.

The gas was effective because it was in such great concentration. The difficulty with the method is that these cylinders are heavy and it is hard to get them up and to get enough of them, and when the gas leaves the nozzle it makes a noise and thus announces the attack. We had a device like a muffler to put on the nozzles so we could discharge our gas without noise, and

our cylinders were very much lighter. Of course, when the American troops got into the war, it was open warfare and there was not so much demand for gas.

The second method is the high explosive shell. A gas shell differs from a high explosive shell only in that the wall is lighter and the method of closing different. A high explosive shell is filled with a high explosive and requires only the fuse to detonate. In a gas shell, however, we must not only have the shell filled with the gas but we must have a little explosive charge to shatter the shell when it reaches its destination. That is the charge which we call the booster—a small explosive charge put into the fuse end. I call your attention to this booster because this was the limiting factor to the production of gas shell in America. The entire gas program was predicated upon the program of the Ordnance Department for supplying shells. We planned to fill all the shell the Ordnance Department would promise to make, and to have gas enough not only to fill those shell but to supply the Allies. As a matter of fact we were ready on April 15, but we got no shell until June, and what held up the entire program was that booster. We got shell in very large numbers but did not get the boosters. The gas shell always has a colored band indicating the type of filling material. With certain sizes of shell the propellant charge is introduced separately in silk bags.

An ingenious method of projecting gas was devised by an Englishman named Livens—primarily with the purpose of providing a gas projectile which would be less costly than the expensive shell then available. The Livens drum, or container, may be roughly described as an eight-inch pipe with a hemispherical end. The propellant was ordinary black powder, as smokeless powder was found to be a little too sudden. To facilitate transportation of the drums, the powder was carried in a separate can and the arrangement of the compartments in this can regulated the range of the projectile. The range of the Livens drums was approximately 1700 yards, the charge being much greater than that of a long-range shell. This method was very successful and comparatively inexpensive.

In the production of the Livens drums, the National Tube Company rendered valuable service and I cannot speak too highly of the important work done by Mr. F. N. Speller and his assistants.

Another cheap and effective method of getting the gas across was the Stokes mortar bomb. The Stokes mortar is named for its inventor, Wilfred Stokes. This mortar, which can be easily carried forward by charging infantry, consists of a thin-walled barrel equipped with light-weight, but rigid, supports which can be adjusted so as to give the barrel the desired elevation and direction. The mortar can be carried conveniently by one man, and can be erected and operated in an improvised trench or shell hole. The bomb, which was of cylindrical form, carried a disruptive charge in the front end; while the base carried a fuse and the propelling charge, the bomb being set off by impact upon the bottom of the mortar. A man stood on each side of the mortar and these men alternately dropped in the bombs.

The above outline briefly presents the general methods of utilizing the gases in warfare. As regards manufacture of these gases in the United States, it may be of interest to describe briefly the developments at Edgewood Arsenal where work was inaugurated by the government as soon as it became apparent that it would be impossible to secure the requisite quantities of gas from private manufacturers.

Two years after the first gas attack the United States entered the war. The country was totally unprepared. Neither gas masks for the protection of our own troops, nor the materials and equipment necessary for utilizing toxic gas in offensive warfare were available. Immediate action was necessary. It was realized that extensive research work would be required to help solve the problems involved, and this task was assigned to the United States Bureau of Mines. The work connected with the development and procurement of the necessary gas masks was assigned to the Surgeon-General's Office; the problem of devising and securing gas shell was turned over to the Artillery Ammunition Section of the Ordnance Department; while the Trench Warfare Section of the Ordnance Department was charged with the procuring of the necessary supply of toxic gas and with the filling

of shell with this material. For the execution of these tasks originally assigned to the Trench Warfare Section, manufacturing and filling plants were necessary, and in response Edgewood Arsenal came into existence. From its original inception, as simply a place for filling shell with gas, it developed with the rapidly changing conditions of war, until at the signing of the armistice it consisted of an enormous industrial plant with a personnel of over 7000 men.

In June 1917, General Crozier had approved the general proposition of building a filling plant. By early fall the plans of the proposed plant were nearing completion, and it became urgent that a suitable site for it be selected at once. Kent Island was suggested, but Congress failed to approve this selection. Later a large tract of land, comprising 35 000 acres near Aberdeen, Maryland, was purchased by the United States Government and set aside as a proving ground under the President's Proclamation, dated October 16, 1917. This ground was well adapted as a suitable site for the proposed filling plant, since it was in an isolated district, was relatively near the embarkation ports, and could easily be provided with both railway and water transportation. Accordingly, about 3400 acres of that portion of the tract known as Gunpowder Neck were set aside for this purpose. Because of this location, the entire project was referred to in early orders under the title of "Gunpowder Reservation" or "Gunpowder Neck Reservation."

The site having been selected, work was soon under way. A railroad spur connecting the ground with the Pennsylvania Railroad was completed in the latter part of October, and actual construction on the filling plant began on November 15.

The entire project centered at Gunpowder Neck remained under the administration of the Trench Warfare Section with Lieut. Col. E. J. W. Ragsdale and Lieut. Col. E. M. Chance in charge, until March 6, 1918. On that date the author of this paper, then Assistant Director of the Gas Service and Chief of the Chemical Service Section, was appointed Colonel in the Ordnance Department and made Commanding Officer of Gunpowder Reservation. The Reservation was thereby withdrawn entirely from the administration of the Trench Warfare Section

and made a separate unit in the Ordnance Department. Early in April the offices were transferred from Washington to Baltimore, while those in immediate charge of planning and constructing the plants took up their quarters at the Reservation itself. Later, on May 4, the name "Gunpowder Reservation" was officially changed to that of "Edgewood Arsenal." The Arsenal remained as an integral part of the Ordnance Department until June 28, 1918, when the Gas Service of the Army was organized into a Chemical Warfare Service with Major General William L. Sibert as its director. The entire organization of Edgewood Arsenal was thereby transferred to the Chemical Warfare Service, reporting to Major General Sibert.

During the winter months of 1917–1918 the work of construction at the Arsenal was rapidly carried forward. Notwithstanding the extreme severity of the winter, the delays incident to lack of proper transportation, and the scarcity and general inefficiency of labor, construction continued night and day and rapid progress was made. Barracks were built for the workmen, officers' quarters erected, and a temporary hospital pushed to completion. A power-plant was built in connection with the first filling plant and a water system installed having a capacity of 9 500 000 gallons a day.

Early in March the filling plant had been completed to such an extent as to admit of limited operation. The necessary shell and explosive charges (the so-called boosters) however, were not available and, in fact, did not become available for many weeks later, and then only in limited quantities.

The amounts of toxic gas called for in the different project programs issued by the War Department increased as the war progressed, and it was foreseen that enormous quantities of raw materials would be required for their manufacture. Foremost among these materials was chlorin; for not only is this gas used directly in wave attacks, but it is the fundamental material required for the manufacture of nearly all the toxic gases used in warfare. The normal chlorin output of the country was entirely inadequate to meet the demands. In order to make up the deficiency, it was finally decided to build at the Arsenal a large chlorin plant with a capacity of 100 tons a day. Construction

began on May 11, 1918, and early in August the first unit was ready for operation. Equipment was provided for recovering in solid form the caustic soda formed in the process, as well as for liquefying half of the total output of chlorin.

It was during the summer of 1917 that the Germans began the use of mustard gas. But little attention was given to this at first. Experience soon showed, however, that for certain purposes this gas was really the most insidious one so far employed. Efforts, therefore, were concentrated upon the development of a commercial process for its manufacture. Different laboratory methods of preparation were known. Apparently, the most promising of these for large-scale production consisted in the interaction between ethylene and sulphur monochlorid under the proper conditions. The reaction, however, requires very careful control and much experimentation was required to work out the most suitable conditions; moreover, sulphur was liberated in the process, and its disposition proved to be a very complicated problem. Finally, in May, it was felt that sufficient information was at hand to justify the building of a large scale plant at Edgewood; although it was recognized that this plant would be more or less experimental at first and would have to be changed from time to time in accordance with the experience gained. Construction of the plant began on May 18, 1918, and the first run was made one month later, on June 18, 1918.

The construction work at the Arsenal was carried on by civilian labor. It was found necessary, however, to use enlisted men for the operation of the plants. Accordingly, increasing numbers of enlisted men were detailed to the Arsenal during the spring and summer as the various plants came into operation, the number of such men reaching 7400 at one period. In order to accommodate the men, the necessary barracks were built and a large hospital, consisting of 34 buildings, was pushed to completion. Both the Y. M. C. A. and K. of C. constructed units, which were provided with ample library facilities and moving picture outfits. During the summer the roadways of the Arsenal were improved and extended, and a fresh-water supply system installed. Three shell dumps, with total floor space of 2.3 acres, a general storage building, with floor space of nearly 2 acres,

and 12 storage magazines, with a total floor capacity of 5.5 acres, were constructed. Additional filling plants were also installed, and adequate provisions made, not only for filling the various sizes of shell, but also Livens drums, incendiary drop bombs, and smoke and gas grenades.

In addition to the projects already noted, the following were also under the supervision of Edgewood Arsenal: Sinking of brine wells at Midland, Mich., and the recovery of bromin from the brine; a plant for the production of brombenzyl cyanid at Kingsport, Tenn., and for phosgene at Bound Brook, N. J. At the time of the armistice there was also under construction at Croyland, Pa., a large plant for the manufacture of diphenylchlorarsine.

The function of Edgewood Arsenal as finally developed was two-fold: The production of toxic gases, and the filling of these into shell. Everything else was subservient to these. Unfortunately, the plants could not be run to their full capacity because an adequate supply of shell and boosters was never available.

Table I gives some figures of output and capacity of the Edgewood plant, which may be of interest.

TABLE I.

PRODUCTION OF TOXIC MATERIALS, IN POUNDS.

	Total, Jan. 1–Nov. 11 1918	Amount shipped overseas	Total monthly producing capacity, Nov. 1, 1918	Estimated capacity, Jan. 1, 1919
*Liquid chlorin	5 446 000	2 935 000	1 790 000	2 200 000
Gaseous chlorin	2 208 000	....	3 000 000	4 500 000
Chlorpicrin	5 552 000	3 806 000	3 000 000	3 000 000
Phosgene	3 233 070	840 000	2 100 000	3 300 000
Mustard gas	1 422 000	380 000	1 800 000	8 000 000
Brombenzyl cyanid	10 000	....	180 000	180 000
*White phosphorus	2 012 000	342 000	200 000	200 000
*Tin tetrachlorid	1 390 000	212 000	182 000	182 000
*Titanium tetrachlorid	362 000	....	60 000	60 000

*Procured from commercial agencies.

From July 1 until the date of the armistice the output of the filling plant was as follows: 424 771 of the 75-mm. shell filled with chlorpicrin, 2009 with phosgene, and 155 025 with mustard oil; 440 153 grenades filled with white phosphorus, and 363 776 with tin tetrachlorid; 25 689 Livens drums filled with phosgene; and 2646 incendiary drop bombs.

Just what was accomplished, however, cannot be adequately set forth in any brief review. Simple descriptive statements, and statistics of production convey nothing of the difficulties involved in developing the methods or in carrying out the processes of manufacture of such highly toxic material; of the delays incident to the severity of the weather, the lack of transportation facilities, and the general inefficiency of the labor available. Neither do they tell the story of the fine spirit and heroism of the men who worked incessantly, exposed to all the dangers of gas warfare on the battlefield.

In the opinion of the writer, there was never before assembled a lot of young fellows with such breadth of vision, such power of accomplishment, and such loyalty to the cause to which they were devoted, as those who worked together at Edgewood.

The signing of the armistice was the signal for the cessation of work. The object for which the Arsenal had been developed was attained. To-day it stands as a silent warning to all the foes of civilization.

The illustrations which follow will give some idea of the plant and of certain operations.

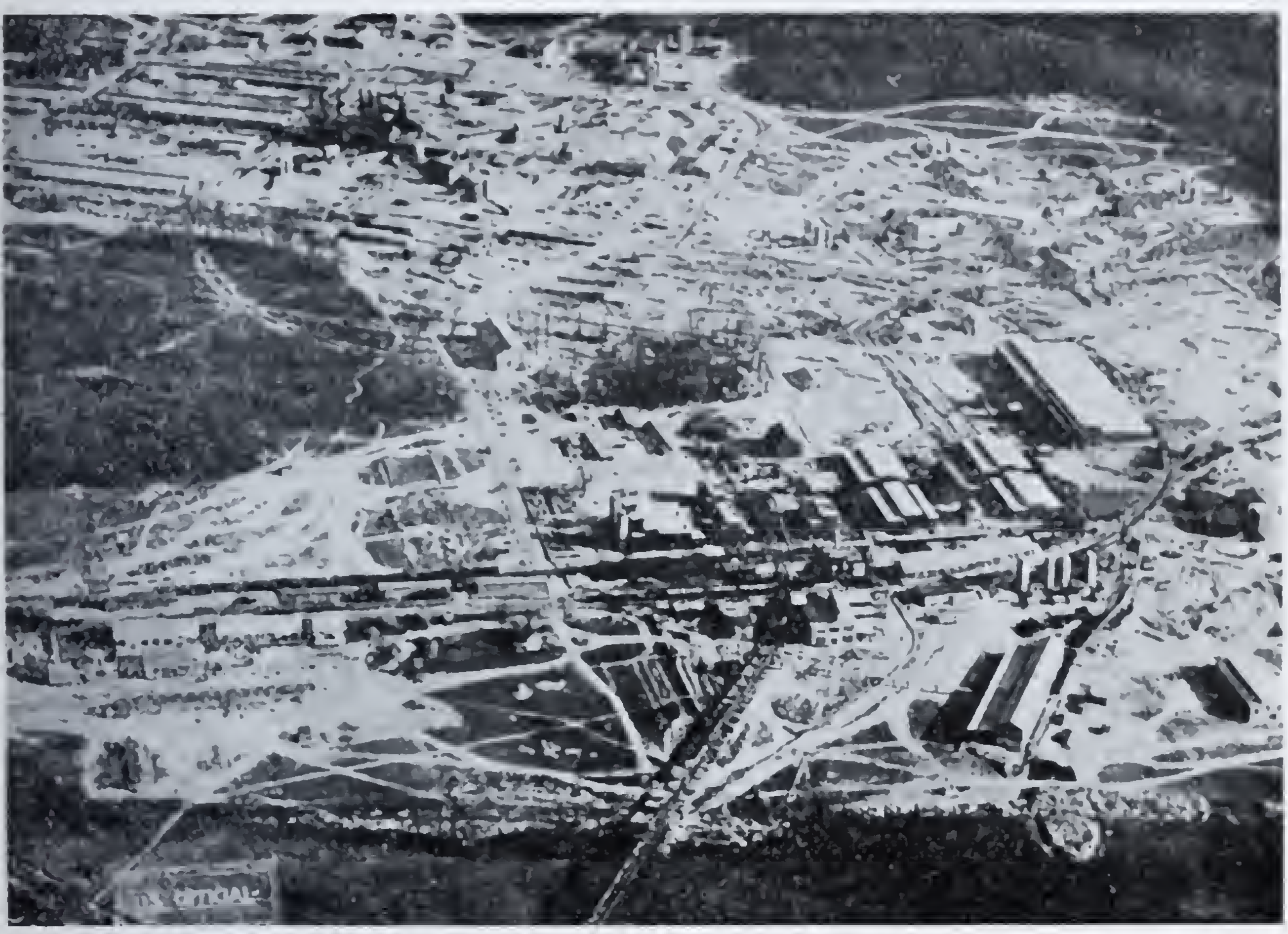

Fig. 1. Aeroplane View of Part of the Arsenal Grounds, Showing the Filling Plants, and the Phosgene, the Chlorpicrin, and the Mustard Gas Plants.

Fig. 2. General View of Chlorin Plant—the Largest Ever Built.

Fig. 3. Interior View of Chlorpicrin Plant.

Fig. 4. Painting and Striping Shell and Livens Drums.

Fig. 5. One of the Eight Cell Rooms of the Chlorin Plant.

Fig. 6. Shell-Filling Machine in Operation.

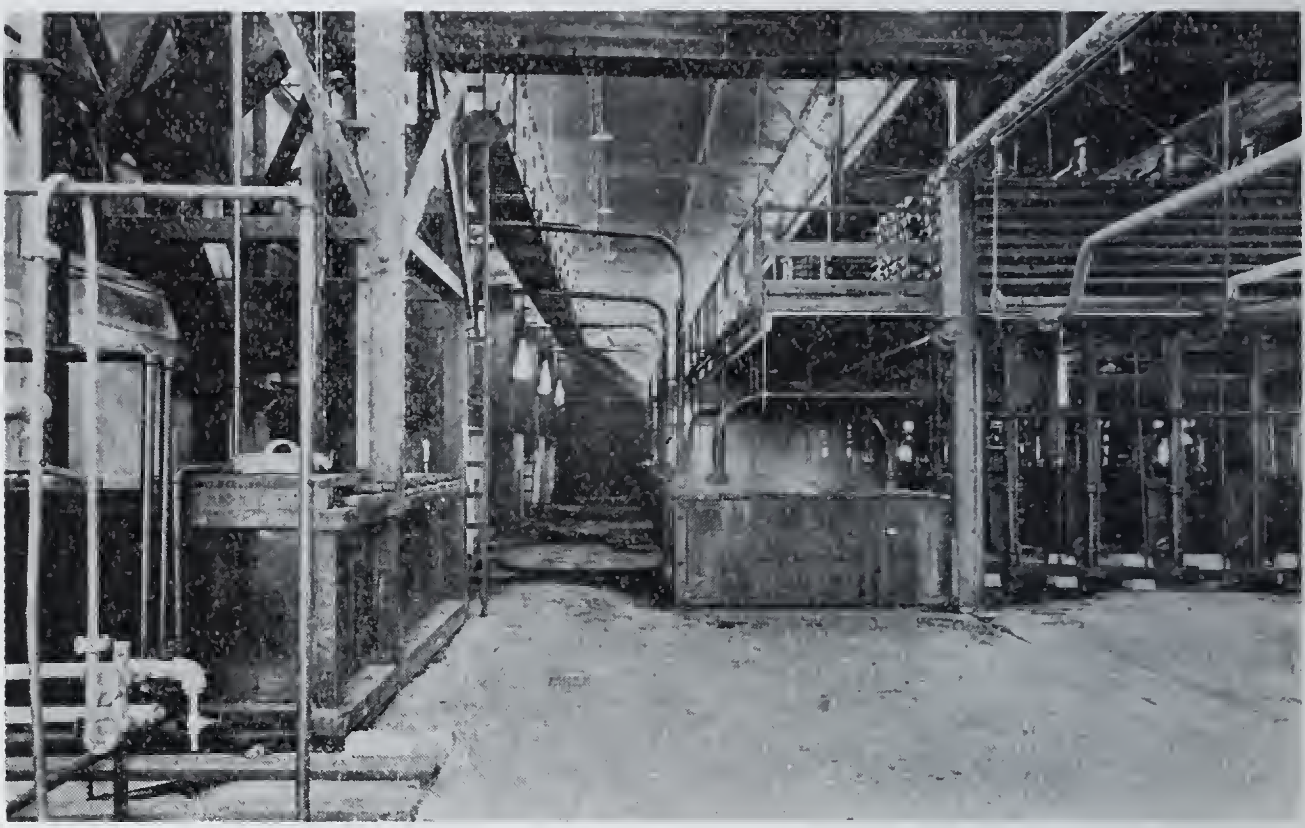

Fig. 7. Interior View of Phosgene Plant.

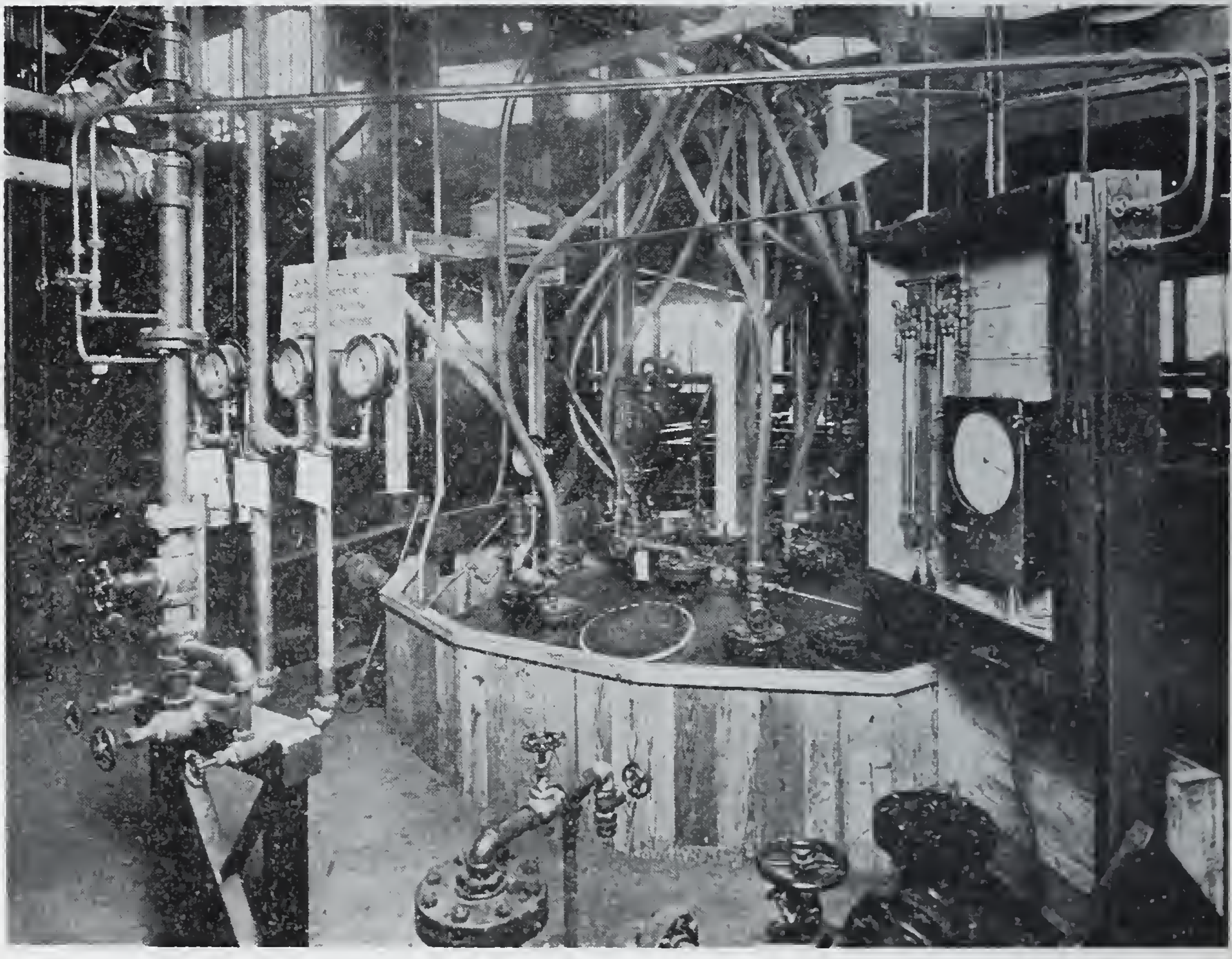

Fig. 8. View of Mustard Gas Unit.

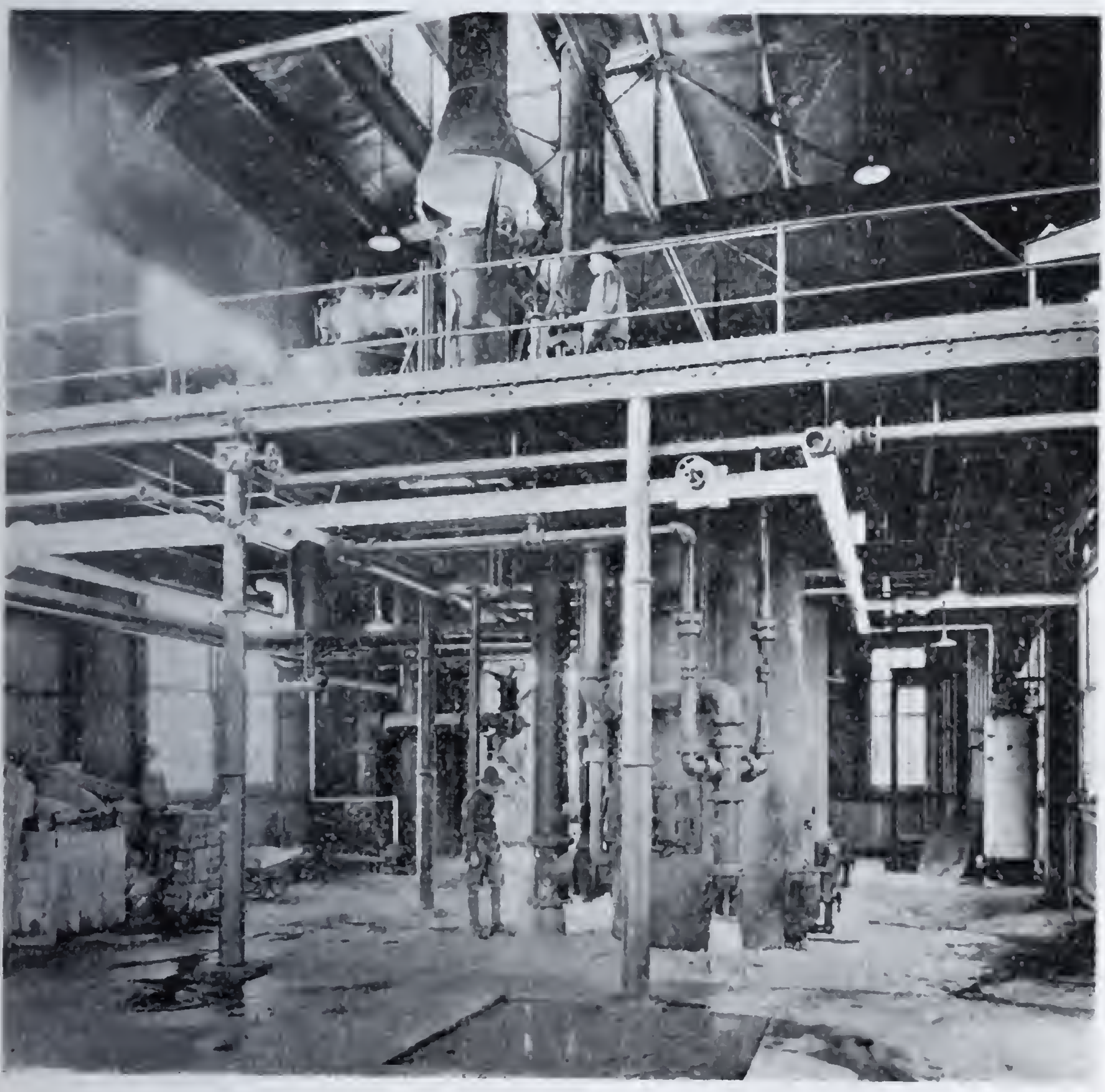

Fig. 9. Carbon Monoxid Producers.

Fig. 10. Interior View of Typical Shell Dump.

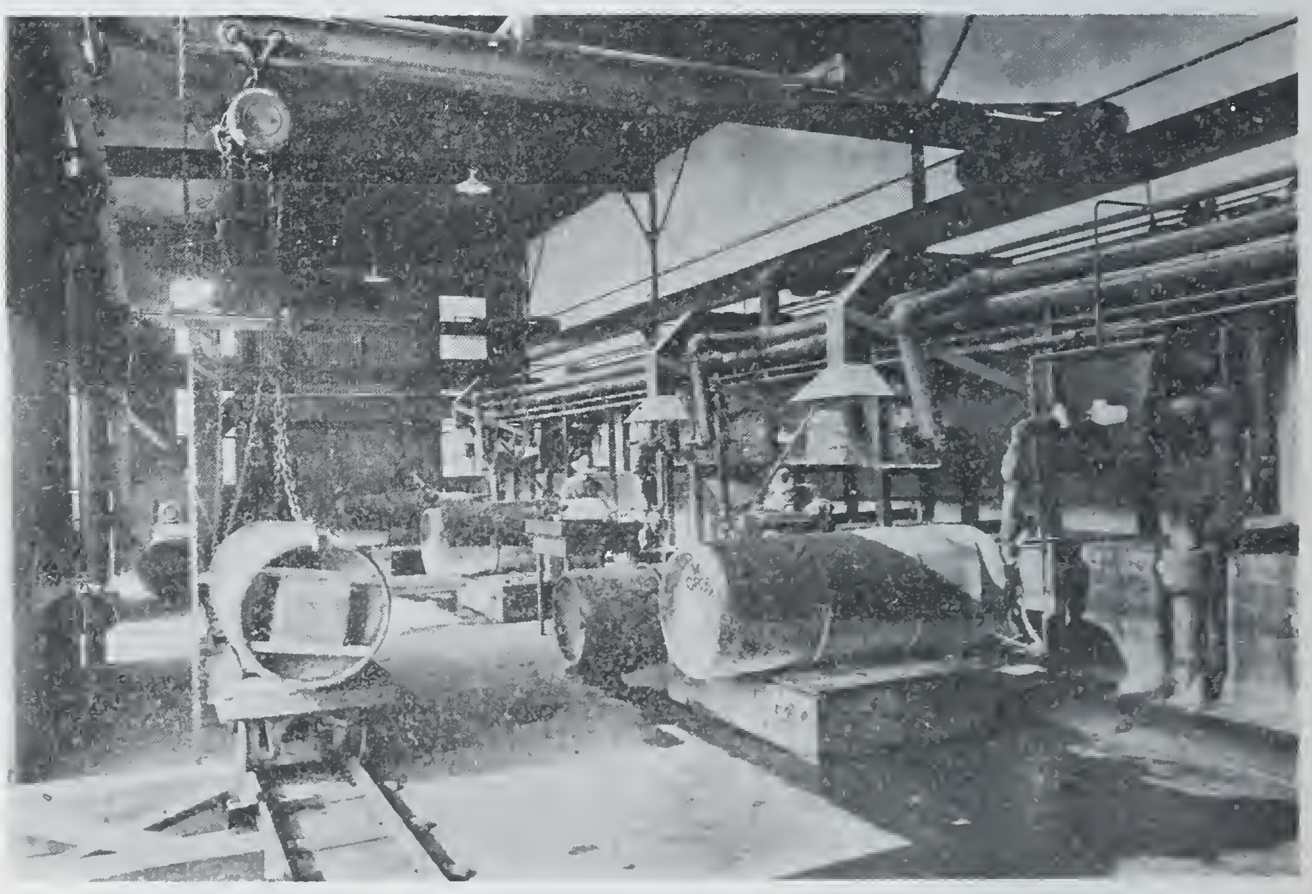

Fig. 11. Filling One-Ton Containers with Toxic Gas.

NOTES ON HEAT TREATMENT OF STEEL

By T. D. Lynch*

OUTLINE

Materials of Design
Standardized Treatments
Results of Standard Heat Treatment
Special Grades of Steel and Special Treatment
Heat Treatment of United States Common Steel Shell
Water Treatment of Six-Inch Shell
Water Treatment of Eight-Inch Shell
Oil Treatment of Six-Inch Shell
Oil Treatment of Eight-Inch Shell
Summary of Tests of Six-Inch Oil-Treated Shell
Conclusions

The heat treatment of steel has come to be a problem with many manufacturing concerns and the recent experience of producing shells for the army and navy has added impetus to this subject.

Materials of Design. For many years the author has been called upon to study the heat treatment of steel, and its application to the design and manufacture of electrical apparatus. This study has shown that, in general, the fewer the specifications employed for the steel and the fewer the processes for its heat treatment consistent with the conditions to be met, the more uniform and satisfactory the results. Special steels, specially treated for special purposes, only too often result in delay of delivery, and frequently in an inferior final product. Observations have shown that a selection from the classes of steels which are in general use and readily obtainable, will produce good results when properly treated by processes thoroughly familiar to skilled heat treaters. Therefore, it is easy to realize that when the designing engineer co-ordinates his work with the metallurgical engineer, only a few classes of steel are really necessary for a large percentage of the purposes for which steel is used.

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The designing engineer, in general, has been found to be quite willing to make use of data carefully worked out and made available for him, but he needs this information in concise form, such as can be easily and definitely specified.

Standardized Treatments. In line with this thought, a few tables are presented which have been prepared from the results of many tests in the laboratories of the Westinghouse Electric & Manufacturing Company, and which have been found very useful in the commercial application of the simpler forms of cast, rolled, or forged steel.

TABLE I

DATA ON MATERIALS

Process specification	Annealing temperature	To be machined	Quenching temperature in oil	Quenching temperature in water	Drawing temperature	Foot-note references
A-1	800°C.	Mach.	k 800°C.	......	300°C.	a b
A-2	800°C.	Mach.	k 800°C.	......	400°C.	a b
A-3	......	......	k 800°C.	......	600°C.	a b
B-1	780°C.	Mach.	......	m 850°C.	300°C.	c
B-2	780°C.	Mach.	......	m 850°C.	400°C.	c
B-3	......	......	......	m 850°C.	650°C.	c
C-1	......	......	......	760°C.	200°C.	d a
C-2	......	......	......	760°C.	300°C.	d a
C-3	......	......	760°C.	......	200°C.	d a
D-1	†775°C.	......	775°C.	......	300°C.	n
D-2	†775°C.	......	775°C.	......	350°C.	e
D-3	†775°C.	......	775°C.	......	400°C.	f
D-4	†775°C.	......	775°C.	......	450°C.	g
D-5	......	......	*775°C.	......	400°C.	h

* Quench in H_2SO_4. † Optional.

a Muffle parts that have been machined to size.
b General use for plain carbon steel 0.35 to 0.55 carbon.
c General use for alloy steels ranging from 0.15 to 0.45 carbon, and for plain carbon steel 0.15 to 0.25 carbon. The higher the carbon the higher the tensile strength for similar drawing temperature.
d Used for treating high carbon steel, such as tool steel.
e Small and medium size springs. Regular spring temper.
f Heavy springs.
g Draw at 450°C. in 50 per cent. each of KNO_3 and $NaNO_3$. Soft spring temper for field coils, etc.
h Springs that must be kept free from oil.
k Axle steel over two inches in diameter should be quenched in water.
m When carbon is over 40 per cent., quench at 825°C.
n Light springs.

Table I is a compilation of data, selected from standard processes, covering the heat treatment of plain carbon and alloy steels for the guidance of the heat treating foreman. The first column indicates the process, designated by letter and sub-number. This is followed in the other columns by the required treatments in their proper sequence. For example, process A-1 is used where the steel is not to be machined after treatment. The piece is annealed to remove any forging or casting strains. It is then machined (rough or smooth finished as the case may require), quenched, drawn and, where accuracy requires it, ground to finished size. Process A-3 is used where the steel is to be machined after having been fully heat treated; that is, quenched and drawn. The foot-notes give such special information as is needed but not readily tabulated, and are self explanatory.

TABLE II

DATA ON MATERIALS

Process specification	Annealing temperature	To be machined	Carbonizing temperature	Annealing temperature	Quenching temperature in oil	Quenching temperature in brine	Drawing temperature
E-1	780°C.	Mach.	*930°C.	780°C.	780°C.	750 to 780°C.	200°C.
E-3	....	Mach.	*930°C.	....	780°C.	750 to 780°C.	200°C.
E-4	....	Mach.	*930°C.	780°C.	780°C.	750 to 780°C.	...
F-1	780°C.	Mach.	*930°C.	780°C.	....	780°C.	...
F-2	....	Mach.	*930°C.	780°C.	....	780°C.	...
F-3	....	Mach.	*930°C.	....	....	780°C.	...
F-4	....	Mach.	*930°C.	780°C.	....	780°C.	200°C.

* Specify depth of case desired, which will govern the time of carbonizing.

G-1. Immerse for 15 minutes in potassium ferrocyanide at a temperature of 735 to 760°C. Quench in water.

G-2. Heat the steel to be treated to a temperature of 735 to 760°C. Apply powdered potassium ferrocyanide. Repeat this operation three times and then quench in water.

Table II is arranged similarly to Table I and is for use where an extremely hard surface and tough core are required.

TABLE III

HEAT TREATED STEEL

MATERIAL	Range of sizes	Process speci-fication	Physical properties: Tensile strength lbs. per sq. in.	Yield point lbs. per sq. in.	Elastic limit lbs. per sq. in.	Percentage of elonga-tion in 2″	Percentage reduction of area	Hardness factor: Brinell	Hardness factor: Scleroscope
Plain carbon steel.	Up to 2″ dia.	A-1	110000	80000	70000	10	25	260	41
C. 0.35-0.50%	Up to 1″ wall	A-2	100000	70000	65000	14	30	220	38
Mn. 0.40-0.80%		A-3	85000	60000	55000	18	40	190	33
P. max. 0.05%	2″ to 4″ dia.	A-1	100000	70000	60000	10	25	250	40
S. max. 0.05%	1″ to 2″ wall	A-2	90000	60000	55000	14	30	210	37
		A-3	80000	50000	45000	18	40	180	33
	4″ to 8″ dia.	A-1	90000	65000	55000	10	25	240	40
	2″ to 4″ wall	A-2	80000	55000	50000	14	30	200	37
		A-3	75000	45000	40000	18	40	170	33
Alloy steel.	Up to 2″ dia.	B-1	180000	160000	130000	10	25	350	55
C. 0.15-0.25%	Up to 1″ wall	B-2	150000	130000	110000	14	35	300	49
Mn. 0.50-0.80%		B-3	100000	85000	70000	22	50	200	35
P. max. 0.05%	2″ to 4″ dia.	B-1	175000	150000	120000	10	25	340	54
S. max. 0.05%	1″ to 2″ wall	B-2	145000	120000	100000	14	35	290	48
Ni. 3.25-3.75%		B-3	95000	80000	65000	21	50	195	34
	4″ to 8″ dia.	B-1	170000	140000	110000	10	25	335	52
	2″ to 4″ wall	B-2	140000	110000	95000	14	35	285	47
		B-3	90000	75000	60000	20	50	190	33
Alloy steel.	Up to 2″ dia.	B-1	180000	160000	140000	6	15	400	60
C. 0.30-0.40%	Up to 1″ wall	B-2	160000	130000	120000	10	30	330	54
Mn. 0.50-0.70%		B-3	105000	85000	70000	20	45	220	36
P. max. 0.04%	2″ to 4″ dia.	B-1	175000	150000	130000	6	15	390	58
S. max. 0.05	1″ to 2″ wall	B-2	150000	120000	110000	10	30	320	52
Ni. 1.00-1.50%		B-3	100000	80000	65000	20	45	210	35
Cr. 0.40-0.75	4″ to 8″ dia.	B-1	170000	140000	120000	6	15	380	56
	2″ to 4″ wall	B-2	140000	110000	100000	10	30	310	50
		B-3	95000	75000	60000	20	45	200	34

TABLE IV

HEAT TREATED STEEL SPRINGS

MATERIAL	PHYSICAL PROPERTIES							Characteristic uses
	Process specification	Tensile strength lbs. per sq. in.	Yield point lbs. per sq. in.	Percentage of elongation in 2″	Percentage of reduction of area	Hardness factor		
						Brinell	Scleroscope	
Spring steel. C. 0.75-0.90% P. max. 0.04% S. max. 0.04% Mn. 0.25-0.50%	D-1	250000	180000	0	0	500	75	For light springs. Too brittle for high frequency.
	D-2	200000	160000	3	30	400	65	Regular spring temper.
	D-3	180000	140000	6	35	350	60	Medium spring temper. For use where D-2 is too hard.
	D-4	160000	130000	10	40	300	50	Soft spring temper for springs used on field coils or similar service.
	D-5	180000	140000	6	35	350	60	For use where springs must be free from oil in order to apply a subsequent finish.

The values given under "Physical properties" are approximately the low limits that may be expected from the processes indicated when applied to parts up to and including $\frac{1}{8}$ inch in diameter or thickness. Heavier parts will be slightly lower in strength and hardness, and correspondingly higher in elongation.

TABLE IV
HEAT TREATED STEEL

MATERIAL	Treatment	Process specification	PHYSICAL PROPERTIES: Core: Tensile strength lbs. per sq. in.	Core: Yield point lbs. per sq. in.	Core: Percentage of elongation in 2″	Core: Percentage reduction of area	Case: Hardness factor: Brinell	Case: Hardness factor: Scleroscope	Characteristic uses
Plain carbon steel. C. 0.10-0.20% Mn. 0.50-0.80% P. max. 0.05% S. max. 0.05%	Carbonizing	F-1	60000	30000	18	35	550	85	Where minimum distortion is required.
		F-2	60000	30000	18	35	550	85	General for carbon steel.
		F-3	60000	30000	18	35	550	85	Carbonized and hardened only.
		F-4	60000	30000	20	40	515	80	Carbon steel parts subject to shock.
Alloy steel. C. 0.10-0.20% Mn. 0.50-0.80% P. max. 0.05% S. max. 0.05% Ni. 3.25-3.75%	Carbonizing	E-1	180000	120000	12	45	550	80	Where minimum distortion is required.
		E-3	180000	120000	12	45	550	80	General for nickel steel.
		E-4	200000	150000	8	35	600	90	Maximum hardness.
Alloy steel. C. 0.30-0.40% Mn. 0.50-0.80% P. max. 0.05% S. max. 0.05% Ni. 3.25-3.75%	Carbonizing	E-1	180000	150000	12	45	600	85	Where minimum distortion is required.
		E-3	180000	150000	12	45	600	85	General for vanadium steel.
		E-4	200000	180000	8	35	650	95	For maximum hardness.
Open-hearth steel. C. 0.10-0.20%	Cyaniding	G-1	60000	30000	22	45	275	55	Surface hardening only.
Bessemer steel. C. 0.15-0.25%	Cyaniding	G-2	70000	35000	15	35	275	55	Surface hardening only. Thin sections liable to be brittle.

Process specifications E and F are carbonizing treatments and when used on the steels indicated give a hard case and a tough core. The sub-numbers 1, 2, 3 and 4 represent different degrees of refinement in the treatment. The tensile properties of the core as given can be taken as the approximate low limit. The hardness of the case is somewhat dependent on the depth of carbonizing

Results of Standard Heat Treatment. Table III is a tabulation of the physical properties to be expected from the material given in column 1, of the sizes given in column 2 and treated by the process given in column 3.

Table IV gives the physical properties to be expected from spring steel when treated by the process indicated in column 2.

Table V gives the physical properties of the core and also of the outside or case, when the steel as given in column 1 is treated by the process indicated in column 3.

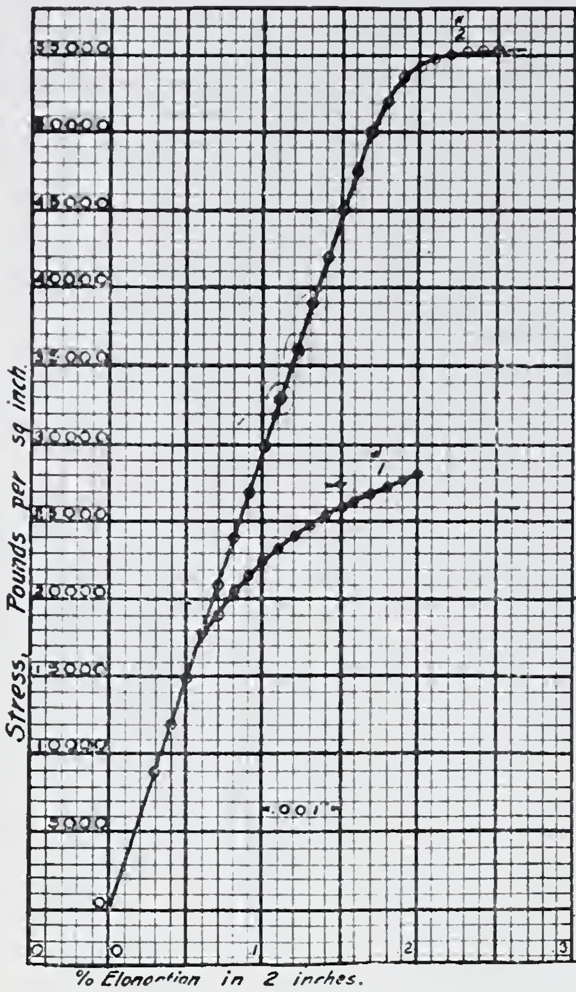
There are special heat treatments, *ad infinitum*, differing from those tabulated, both in the treating process and in physical results obtained. Some of them are likewise well adapted to the steels of large tonnage but these tables are introduced, not to show something new or unusual, but to emphasize the fact that there are certain grades of steels made in large tonnage which, when properly treated by processes that are well known to steel heat treaters, may be relied on to give results suitable for a very large percentage of the uses to which steel is applied.

These tabulated treatments, and resultant physical properties of the several classes of steel given, are intended to cover the simple forgings, such as bolts, studs, shafts, castings and similar objects, which constitute a relatively large tonnage.

Special Grades of Steel and Special Treatments. While it is desirable to adhere to standard grades of steel, heat treated by standard processes, there is a real need for a limited quantity of standard grades of steel for special treatments; special grades of steel for standard treatments; and perhaps, in rare cases, special grades of steel treated by special processes.

For example; there is considerable use for open-hearth screw stock with carbon 0.15 to 0.25 per cent., manganese 0.60 to 0.90 per cent., phosphorus below 0.05 per cent., and sulphur 0.075 to 0.13 per cent. This material, when treated by process B-3 of Table I, will give a superior bolt material, tough and ductile.

A test on this material is shown in Fig. 1 where the true elastic limit has been thus increased from 18 000 pounds to 52 000 pounds per square inch, while the ductility has not been decreased. This material, both in the treated and untreated condition, is relatively free cutting, giving a clean thread or a smooth turned.



OPEN HEARTH AUTOMATIC SCREW STOCK.

Chemical Analysis:
C-.15-.25%, Mn.-.60-.90, S.-.075-.13, P not over .05.

Sample No.	1	2
Annealed at	as received	
Quenched in		
water from		850°
Drawn at		650°
Tensile Strength	59250	84100
Yield Point	35000	55750
Elastic Limit	18000	52000
% Elong. in 2"	34.2	30.2
% Reduction Area	55.0	65.2

Treated in 1" round, then machined to standard .505 dia. test specimen.

Fig. 1. Test of Heat-Treated, Open-Hearth, Screw Stock.

drilled, or milled surface. Our experience in forging and machining about 1000 tons of open-hearth screw stock into nose bushings for shells, has proven its forging and machining qualities, while tests from time to time have verified its physical properties. The high-sulphur, open-hearth, screw stock, to which sulphur has been added in the process of manufacture and which still produces a tough material, must not be confused with the same analysis in Bessemer screw stock nor with open-hearth steel not properly refined, both of which may be brittle.

Heat Treatment of United States Common Steel Shell. The manufacture of steel shell during the past few months has brought in heat treating problems new in details to many of us, yet the principles involved in the final solution are found to coordinate very closely with the processes given in Table I and the results given in Table III.

A great deal of experimentation was necessary, however, before the ideas of the officers of the Ordnance Department, the steel manufacturers, the steel forging companies, and the shell machiners—who also did the heat treating—could be harmonized.

The final specifications on which large orders were placed for the steel billets from which to manufacture United States common steel shell, called for the following chemical analysis:

Carbon, 0.45 to 0.63 per cent.; manganese, 0.50 to 0.90 per cent.; phosphorus and sulphur, both below 0.05; and silicon, 0.20 to 0.30 per cent.

This steel lends itself readily to heat treatment by process A-1, A-2, or A-3 of Table I, as required, with a correspondingly higher tensile strength and elastic limit than that shown in Table III in proportion to the higher carbon content. However, it required experimentation, persuasion, etc., before the proper heat treatment could finally be agreed upon.

Orders called for large numbers of shell of definite form and size, so it was necessary to devise special methods of handling them from the point of view of economical production, as well as to work out the treatment that would give satisfactory physical results.

Some of the experiences of the Westinghouse Electric & Manufacturing Company in solving this problem are introduced to show the extent of the experimentation necessary to establish the processes to be followed in treating shell. The final processes were very close to those given in Table I, simply modified to suit the difference in carbon content. Several methods of heat treatment were tried with varying degrees of success.

Water Treatment of Six-Inch Shell. The first method was that of water spraying the six-inch shell both inside and outside at the same time.

The shell were heated in a continuous furnace similar to that shown in Fig. 2. After the shell were properly heated they were quenched, nose down, as shown in Fig. 3. The tank consisted of an open-bottom, annular chamber, A, with 3/32-inch holes drilled on the inside, and connected, by means of two two-inch pipes, with the water-main at 110 pounds pressure. A ¾-inch pipe, B, perforated with 3/32-inch holes, and extending up through the middle of the quenching chamber, was also connected to the water-main. Supports, C, and guides, D, mounted on springs, E, provided means for mounting the shell in the

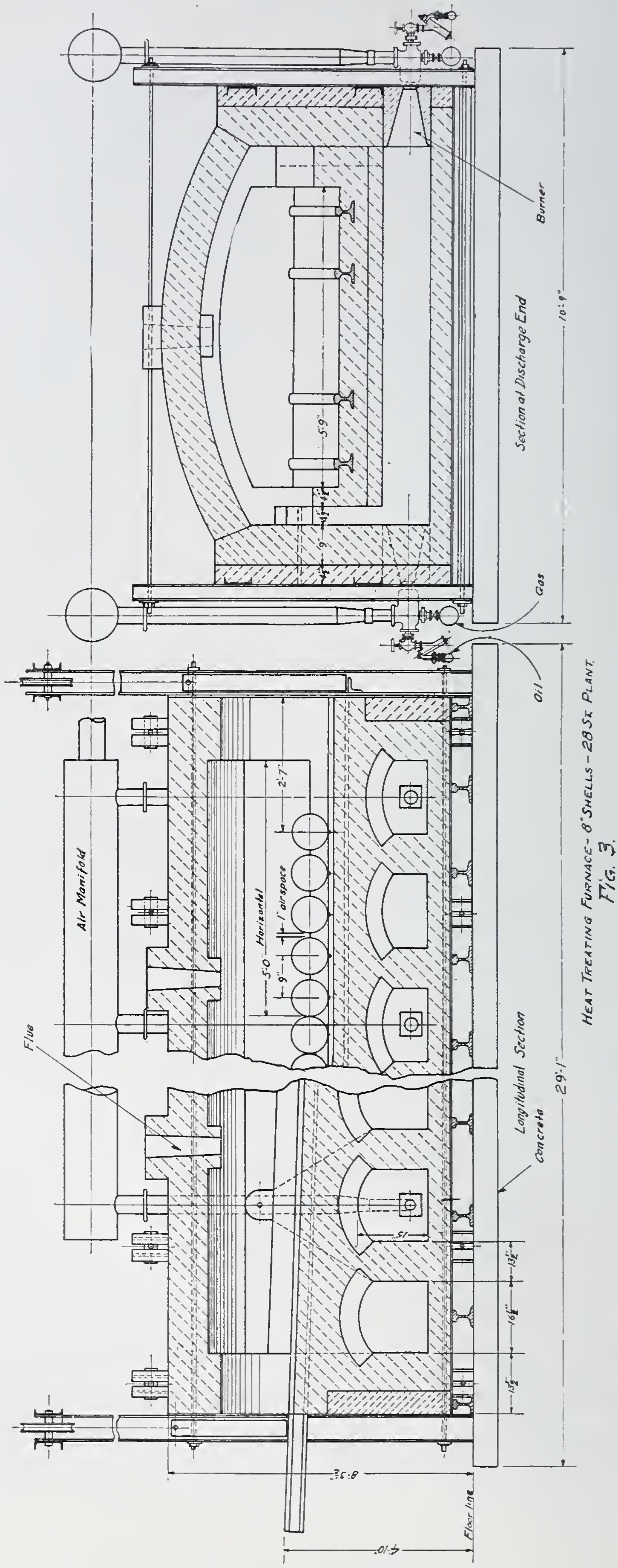


Fig. 2. Heat-Treating Furnace for Eight-Inch Shell. Bottom-Fired Type.

quenching position. The hot shell, F, was placed in the position shown and the opening of a single valve applied the spray simultaneously to the inside and outside of the shell.

This treatment was found to be too drastic and to cause excessive breakage.

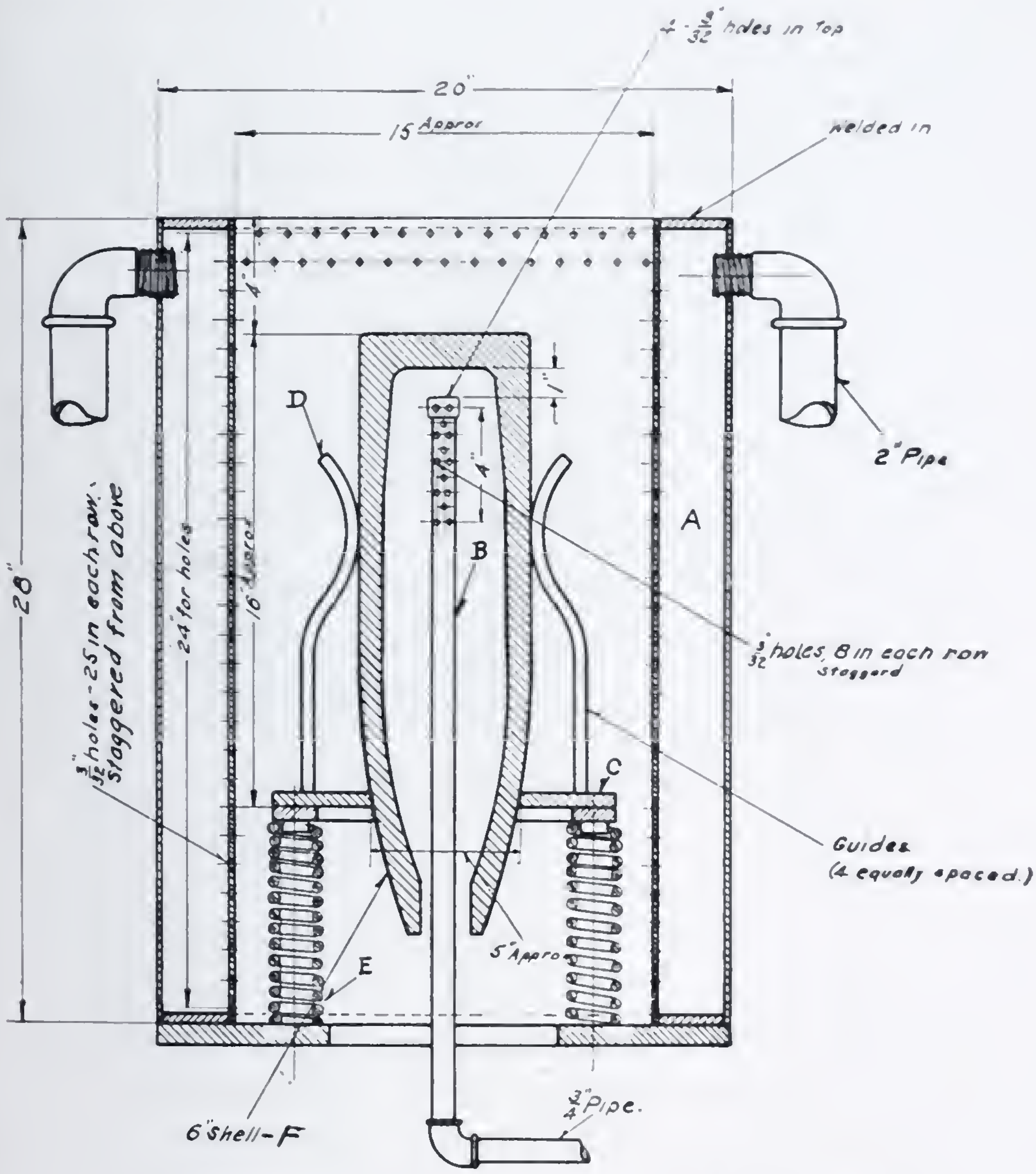


Fig. 3. Quenching Tank for Six-Inch Shell.

The second method consisted in modifying the equipment shown in Fig. 3 by welding a bottom in the quenching chamber, A, removing the two-inch pipe connections and allowing the 15-inch diameter space to fill with water. The hot shell was placed in the water over the pipe, B, and the water turned on, forcing the water to flow down and out at the nose of the shell. Examination showed that the shell was too soft at the base end and too hard at the nose.

Another change was made by replacing the perforated pipe, B, by a solid pipe, leaving off the cap at the end, and then permitting the water to flow freely against the base of the shell on the inside, forcing the water down and out at the nose. By this method 30 000 six-inch shell were successfully quenched and immediately drawn, the shell meeting all Government tests.

Water Treatment of Eight-Inch Shell. The third method was worked out for heat treating eight-inch shell, and included careful handling through the furnaces as well as through the quenching operations.

All eight-inch shell were rolled through the continuous bottom-fired furnace, shown in Fig. 2. The floor of the furnace was built on a slope of 0.7-inch per foot, from the ingoing end to a notch in the rail five feet from the outgoing end of the furnace. Up to the point where this notch is reached, the shell lie against each other, but from this position they are hooked from notch to notch, thus separating the last four shell one inch from each other, as shown in Fig. 2, in order to allow the final soaking temperature of 780 to 800 degrees C. to saturate the shell equally in all parts. The shell were then hooked onto a plate in the door of the furnace where they were picked up by tongs and quenched in the tank shown in Fig. 4. The shell was first dropped nose down in the flaking block, B, to remove loose turnings or scale, and then picked up by another pair of tongs mounted on an air hoist and lowered quickly into the quenching tank, A, with an inch pipe, C, extending up into the shell, with the end of the pipe about one inch from the bottom of the shell. Cold water was turned on until the shell was cold and the shell was then removed to the drawing furnace.

This practice resulted in very large breakage and required modification.

The fourth method was similar to the third, except that the water was turned on for 1¼ minutes, after which the shell remained in the tank an additional ¾ of a minute, but was still quite hot. The shell were then removed from the bath and immediately placed in a drawing furnace at 610 degrees C. (1130 F.). After each quenching operation the water in the quenching tank was left warm for the next shell.

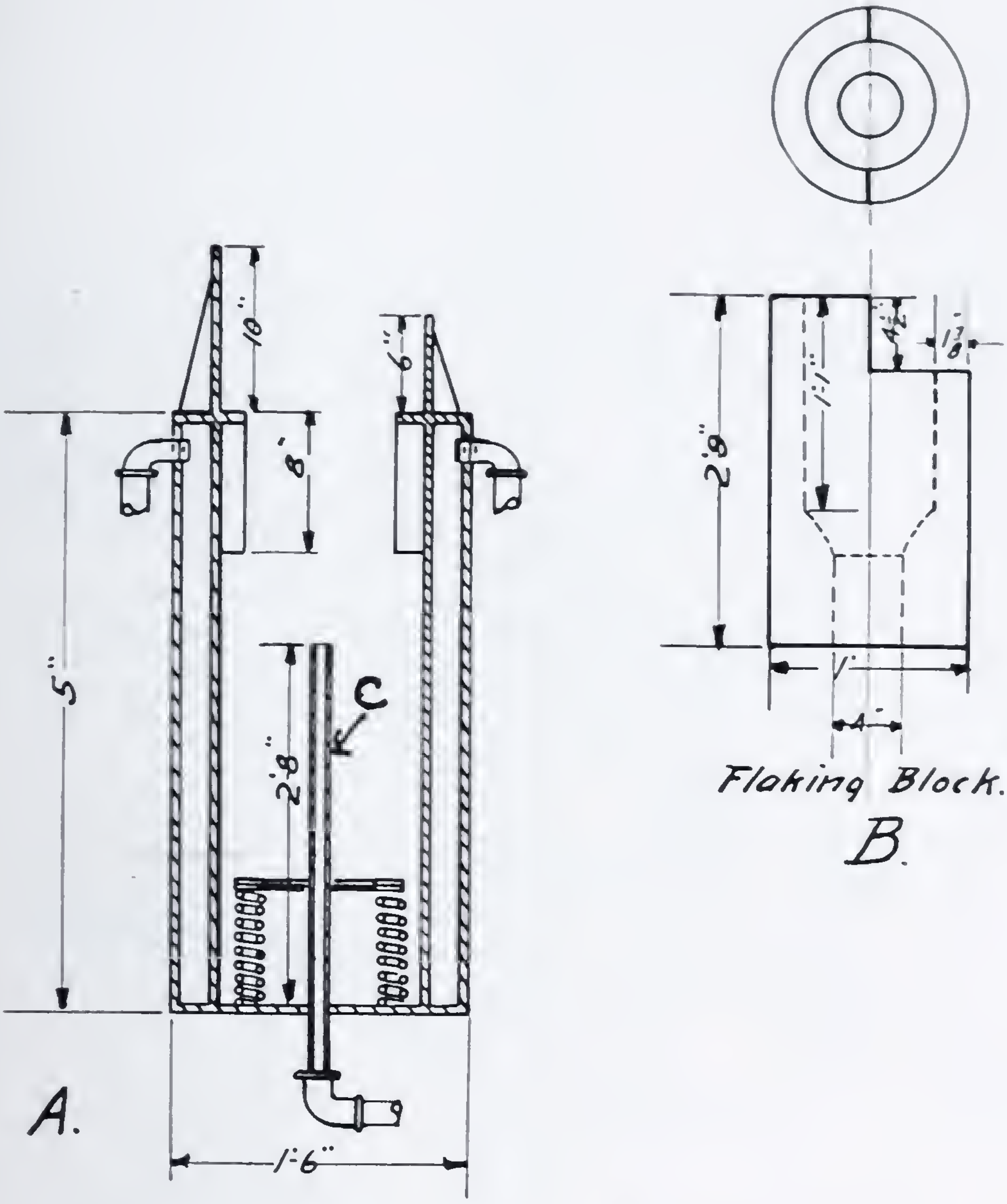


Fig. 4. Quenching Tank for Eight-Inch Shell.

This method of quenching gave good grain structure without any loss from breakage, and the quenching effect proved to be very uniform in different parts of the base and wall sections as shown in Fig. 5. This figure shows longitudinal and transverse sections cut from an eight-inch shell treated by this method. Brinell tests made on the inside, outside, and edge of the section, from nose to base, and on the outside and edge of the ring cut 15 inches from the base end, illustrate the remarkable uniformity produced by this process. About 90 000 eight-inch shell were successfully manufactured on this basis, easily meeting the minimum physical properties of 90 000 pounds per square inch tensile strength; 45 000 pounds per square inch elastic limit by the scribe method; and 18 per cent. elongation in two inches.

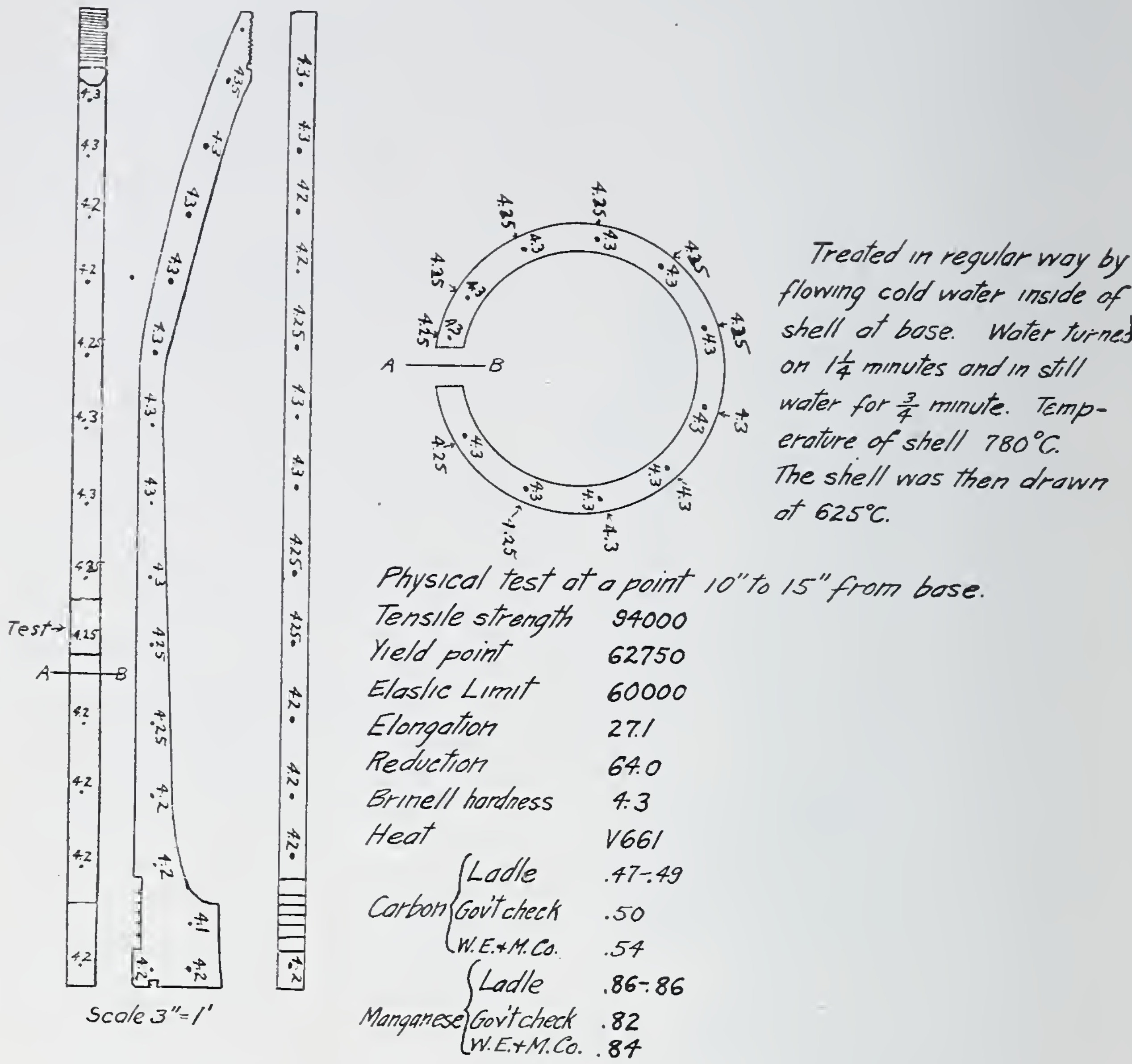


Fig. 5. Uniformity Test of Eight-Inch Shell.

This process had only proven its merits when orders were issued from headquarters at Washington to change from water to oil as a quenching medium.

Oil Treatment of Eight-Inch Shell. On account of the above official decision, the fifth method was worked out, and was of necessity an oil quench. In this method the shell were heated in the continuous furnace just as in the fourth method. The shell were rolled out of the furnace by hand, conveyed on rollers to the quenching tank (Fig. 6), and quenched for three minutes in a vertical position with the nose resting on the bottom angle of a hoist, which, in turn, lifted the shell from the oil, and drained and delivered it to the roller conveyor leading to the drawing furnace.

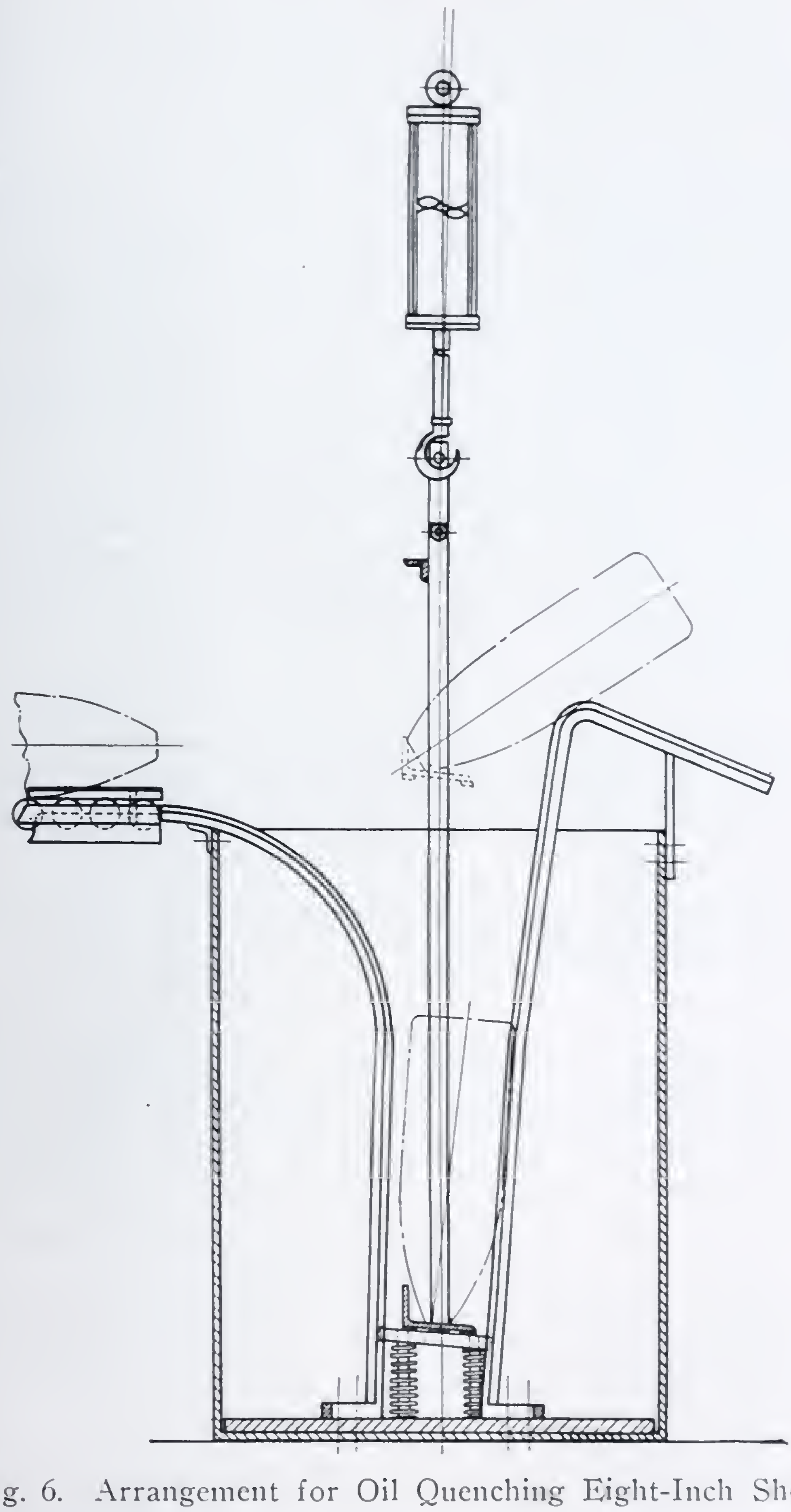


Fig. 6. Arrangement for Oil Quenching Eight-Inch Shell.

Each drawing furnace was large enough to hold 66 shell at one time, and the manufacturing conditions made it necessary to draw them at various lengths of time so that a schedule was worked out covering the number of shell per hour taken from the

furnace for each class of steel. On the basis of 40 shell per hour, Class A steel was drawn at 610, Class B at 625, and Class C at 640 degrees C.; whereas when 30 shell per hour were drawn, the temperature was reduced 10 degrees C., and when 50 shell per hour were drawn, the temperature was increased 10 degrees C. for each class of steel. The ingoing end of the furnace was kept at a higher temperature than the outgoing end, or soaking zone, where the shell reached their maximum temperature. A recording pyrometer gave a continuous record of the soaking zone, which, with two indicating pyrometers, one at each end, gave the operator full control of his furnace temperature.

The classes of steel were determined by the carbon content and hardening numeral, the hardening numeral being the sum of three times the carbon plus the manganese, and the classes worked out were as follows:

Class A. Carbon, 0.45 to 0.51; hardening numeral, 198 to 223.
Class B. Carbon, 0.52 to 0.58; hardening numeral, 217 to 242.
Class C. Carbon, 0.57 to 0.63; hardening numeral, 240 to 265.

This method was successfully carried out until the completion of all orders for eight-inch shell.

Oil Treatment of Six-Inch Shell. A new design of furnace of the over-fired type, shown by a diagram in Fig. 7 and by a photographic reproduction in Fig. 8, was provided for the treatment of the six-inch shell. The shell were rolled through the furnace, in the same manner as the eight-inch shell already described, and were conveyed from the furnace to the quenching tank on rollers. The quenching arrangement is shown by a diagram in Fig. 9 and by a photographic reproduction in Fig. 10.

The shell were placed in a counterbalanced arm support, B, at the end of the tank, by means of which the shell were mechanically lowered into the oil, and rolled through the oil by means of an endless chain, D. This chain conducted the shell to an elevator, E, which lifted them from the oil, automatically drained them, and placed them on a roller conveyor leading to the drawing furnace.

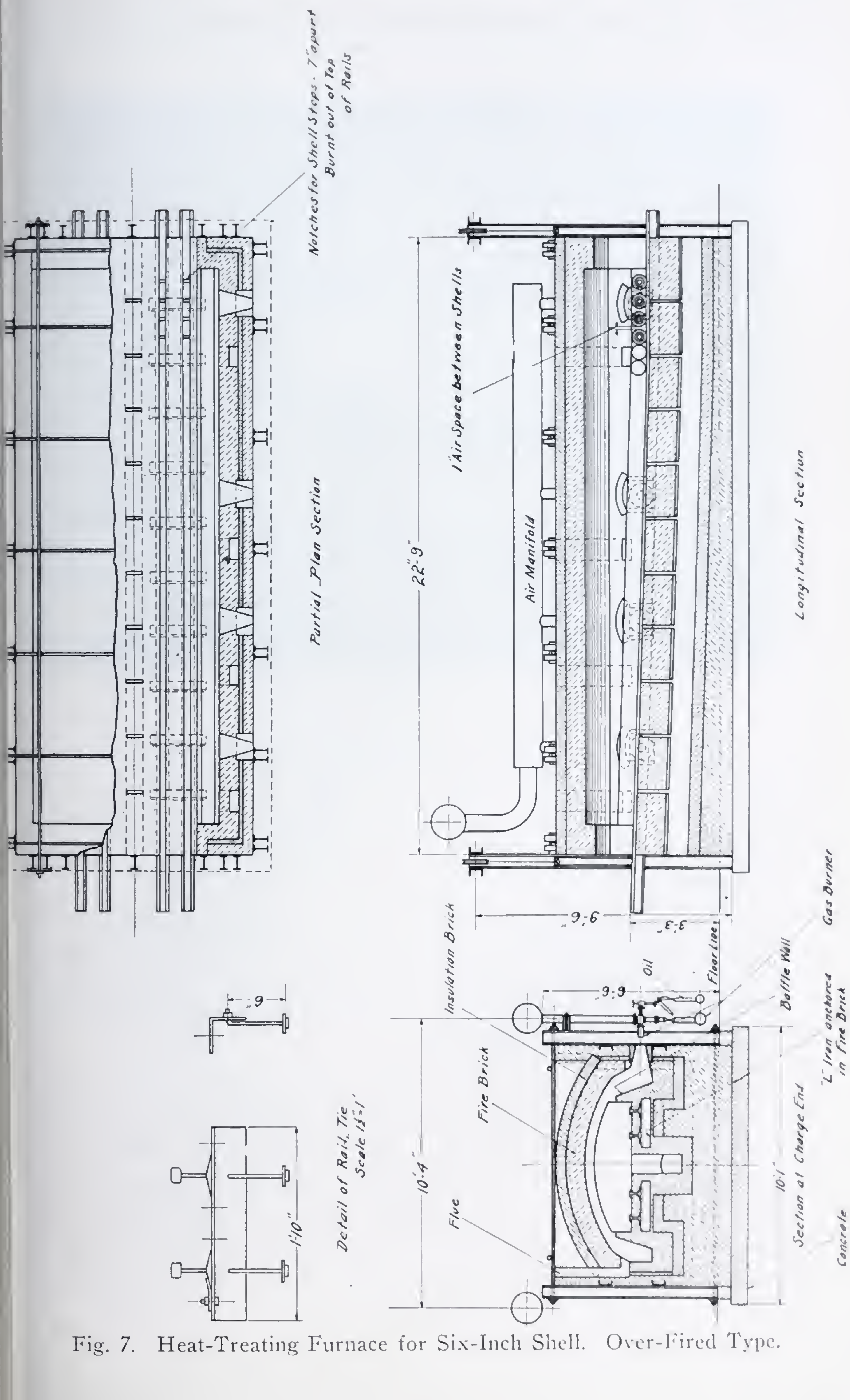


Fig. 7. Heat-Treating Furnace for Six-Inch Shell. Over-Fired Type.

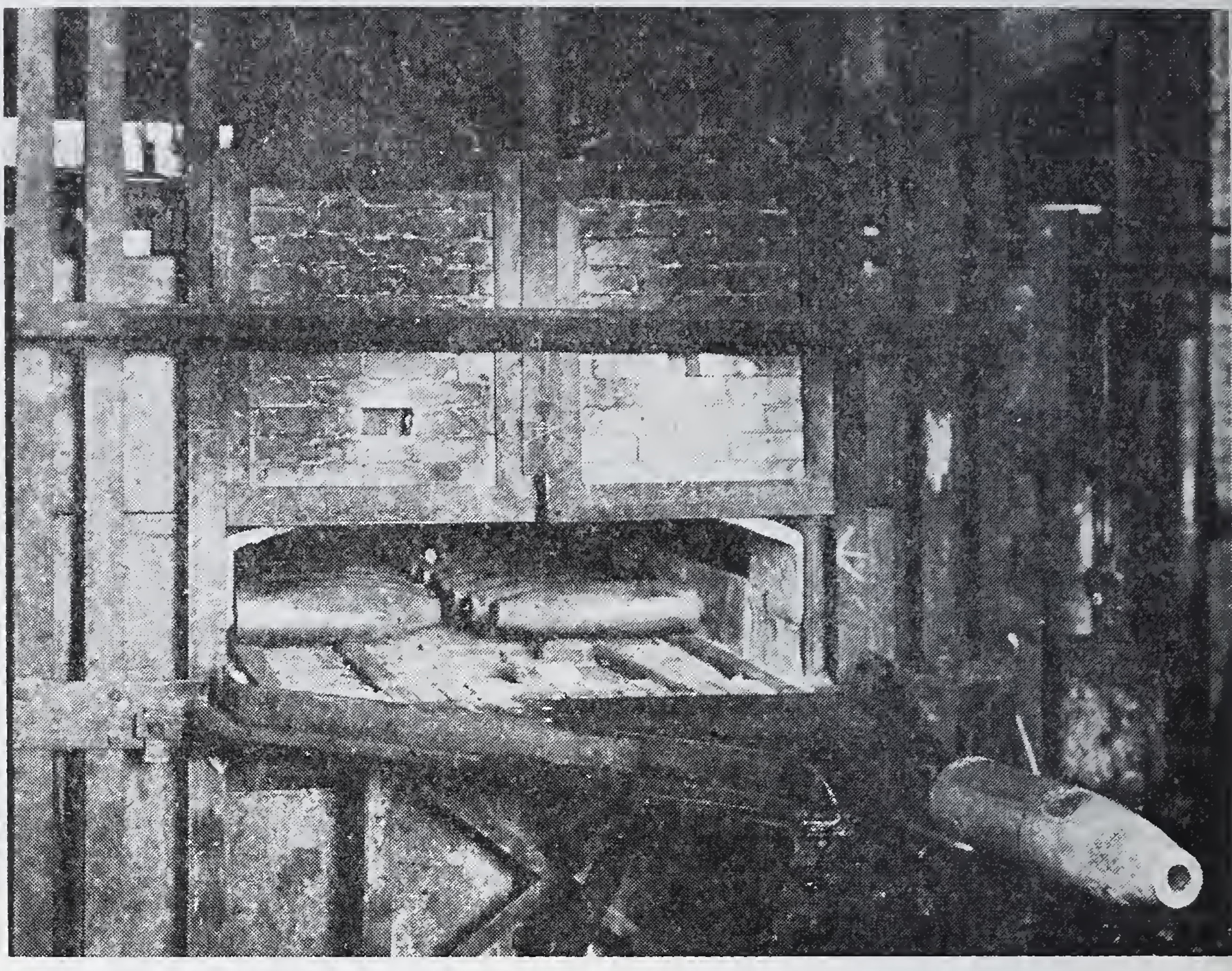


Fig. 8. Heat-Treating Furnace for Six-Inch Shell. Over-Fired Type.

The drawing furnace was similar to the quenching furnace, each furnace holding 80 shell. The shell were left in the furnace for approximately one hour, the temperature varying with the class of steel, similarly to the practice described for the eight-inch shell.

The physical properties required to be met on the greater portion of these shell were the same as for the eight-inch shell, but later the requirement for elastic limit was raised to 60 000 pounds per square inch, which necessarily required a correspondingly lower drawing temperature.

Summary of Tests of Six-Inch, Oil-Treated Shell. Table VI is a tabulation of the results of the physical tests compiled from the test records of 882 of the six-inch shell, which were oil quenched and drawn. This table is arranged in groups according to the Brinell hardness numeral. The first column gives the number of tests in each group. The second and third columns give the Brinell diameter of indentation, with the corresponding

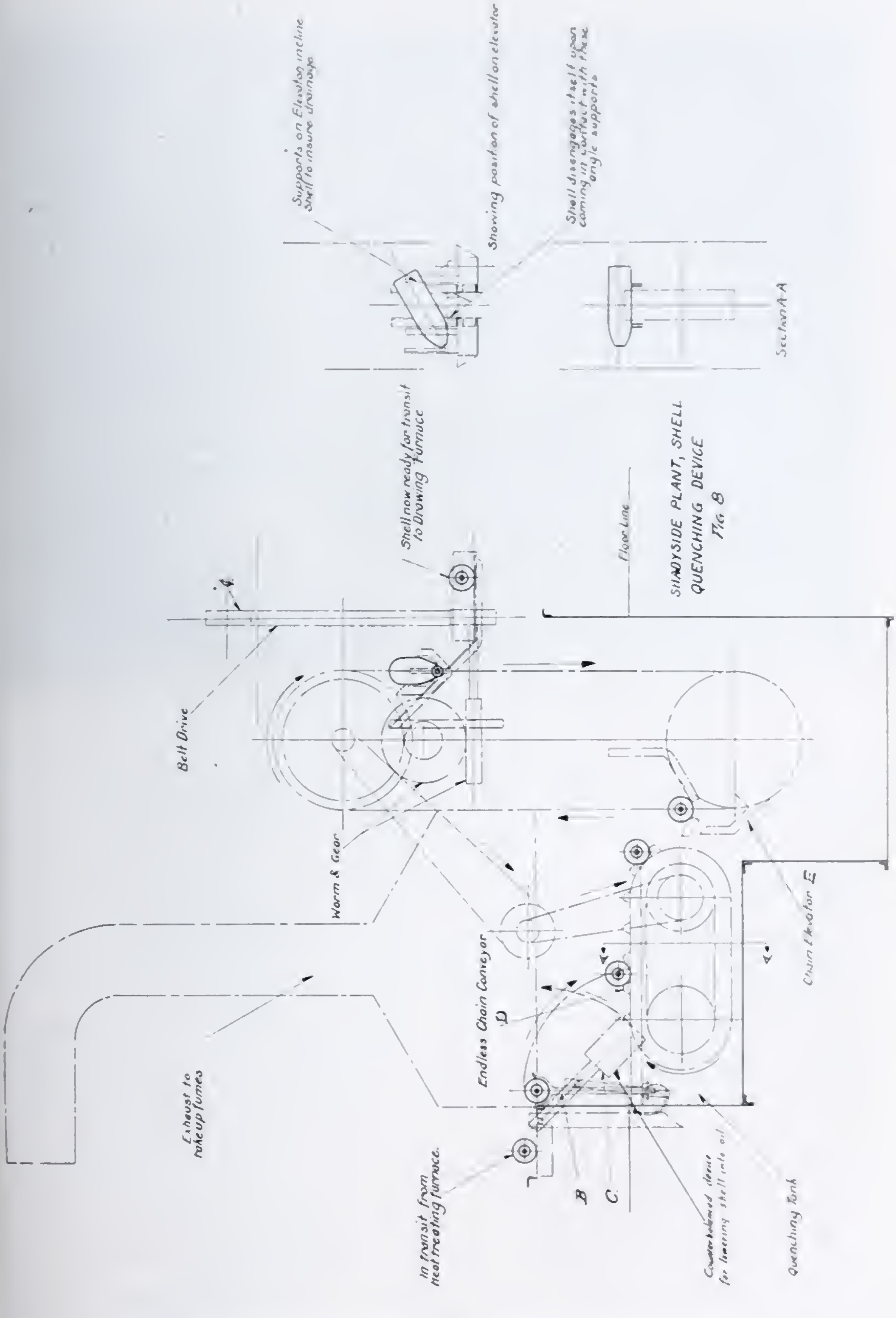


Fig. 9. Arrangement for Oil Quenching Six-Inch Shell.

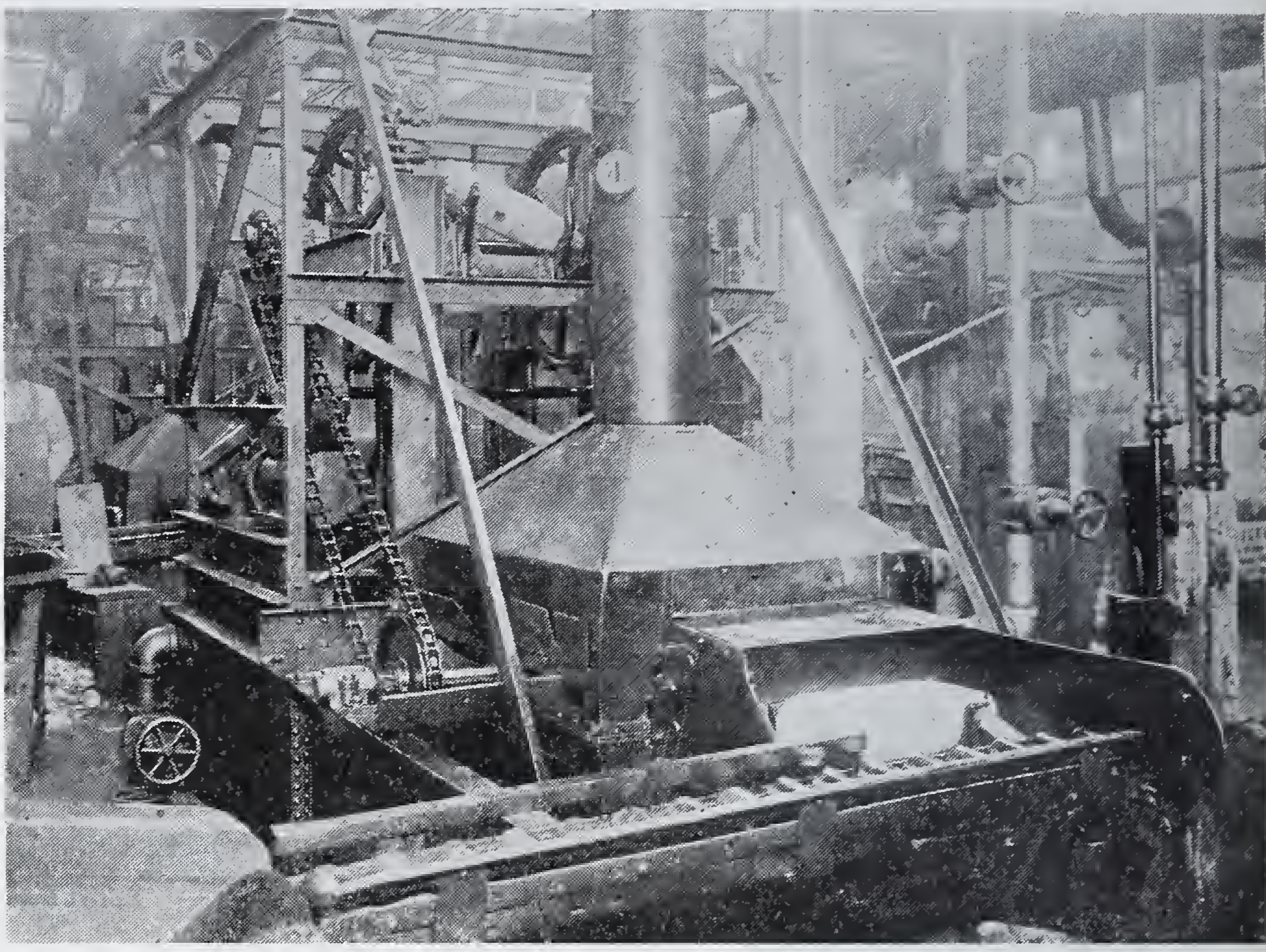


Fig. 10. Arrangement for Oil Quenching Six-Inch Shell.

hardness numeral; each group varying by 0.1 millimeter diameter of indentation from 3.8 to 4.6 millimeters. The fourth, fifth, and sixth columns give the average carbon and manganese content together with the corresponding average hardening numeral equal to 3C. + Mn. for each group. The last four columns give the average, maximum, and minimum tensile strength, elastic limit, elongation, and reduction of area, for each group.

From preliminary tests, it was apparent that a minimum Brinell hardness of 207 (4.2 diameter) was necessary to meet 45 000 pounds per square inch elastic limit; although it was afterwards found that a hardness of 187 (4.4 diameter) would give 45 000 elastic limit if the carbon was not less than 0.51 per cent. and the hardening numeral not less than 207. A maximum hardness of 255 (3.8 diameter) was also established in order to keep the shell within commercial machining range. When it came to meeting the elastic limit of 60 000 pounds as a minimum, it was found necessary to raise the minimum Brinell hardness to 228 (4.0 diameter) and, in order to have a working range, the upper

limit was correspondingly increased, thus very much increasing the machining difficulties. The diameters of identations were observed to the nearest 0.1 of a millimeter on all Brinell tests.

TABLE VI

ALL CLASSES OF SIX-INCH SHELLS—882 TESTS

No. of Tests	Brinell		C.	Mn.	Hardening numeral	Tensile strength	Elastic limit	Percentage elongation	Percentage reduction of area
	Diameter	Hardness							
4	3.8	255	0.59	0.83	2.59	123300 120080 117620	74000 70680 67080	21.0 20.4 19.7	52.1 50.8 48.9
20	3.9	241	0.56	0.75	2.44	133760 115280 98530	74750 66220 42710	25.2 22.0 20.0	61.3 53.4 48.3
133	4.0	228	0.54	0.75	2.38	120500 109660 90250	75000 63120 48900	28.6 23.7 18.9	62.0 55.1 41.2
231	4.1	217	0.54	0.72	2.35	118120 106040 87300	73220 60630 44600	28.8 24.1 17.7	64.0 55.0 36.7
293	4.2	207	0.52	0.70	2.28	115250 100580 84130	68100 57920 42710	31.1 25.6 19.2	68.1 57.3 40.9
147	4.3	196	0.50	0.68	2.20	112410 95250 83930	64100 54650 41000	31.2 26.6 16.8	69.1 58.4 50.2
36	4.4	187	0.51	0.69	2.23	106750 92320 82080	59900 51540 42650	32.5 27.3 19.9	67.8 56.1 37.1
11	4.5	179	0.51	0.72	2.24	97200 89850 84670	57000 49770 40550	31.4 28.6 25.9	68.0 59.6 51.7
7	4.6	170	0.54	0.74	2.37	92220 88640 84470	52250 44800 39880	31.4 28.8 26.1	61.3 54.3 42.2

The average physical properties given in Table VI are shown diagrammatically in Fig. 11, where tensile strength, elastic limit, and elongation are plotted as ordinates and Brinell hardness as abscissas. A study of these curves shows a marked relation between the Brinell hardness and the tensile tests that

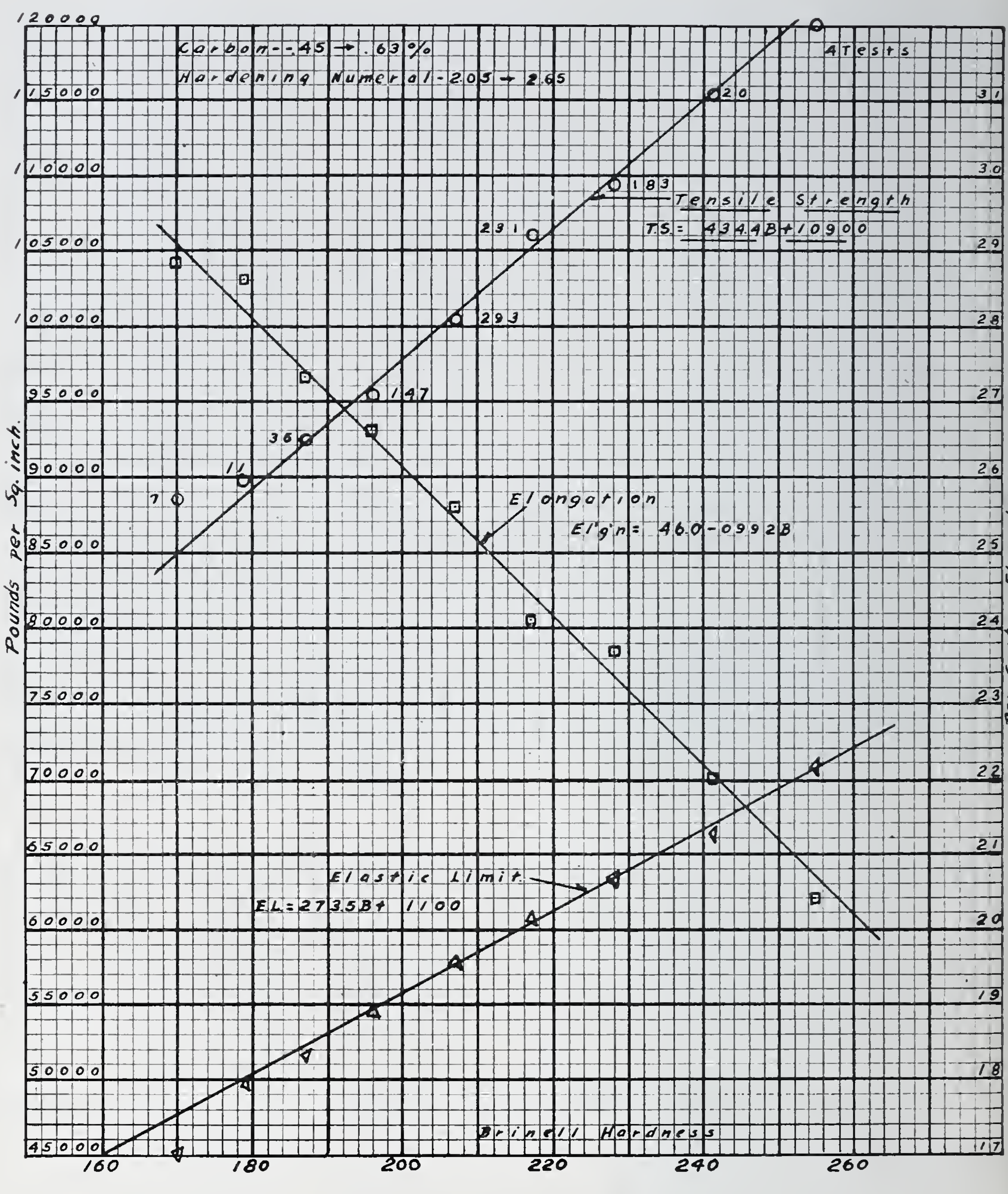


Fig. 11. Chart Showing Results of Heat Treatment of Six-Inch Shell. Based on 882 Tests.

may be expected when a given material of definite section is treated in a similar manner.

On the contrary, the test records of shell, untreated or treated differently from those in this diagram, gave a widely diverging relation between the Brinell hardness and the other physical properties.

Conclusions. A comparison of process A-3 in Table I with the shell treating process as finally worked out, and a comparison of the physical properties given in Table III for plain carbon steel with the test results on six-inch shell shown in Table VI can but emphasize the fact that the problem of heat treating plain carbon steel is a verification of old processes carefully followed, rather than any new development.

This rather extensive reference to the work done in the heat treatment of United States common steel shell simply illustrates the great amount of development so often found necessary when working out and establishing an equipment and process best adapted to commercial manufacture. The main features that entered into this problem, most of which enter into every heat treating problem, emphasize the importance of uniformity of material and accuracy in carrying out of the processes.

The relative smoothness of the surface of the steel pieces, their freedom from scale, and variation in cross section, the proper heat distribution in the furnace to produce even heating, and uniform soaking temperature, the temperature regulation, control and general layout suitable for drawing immediately after quenching, and the greatest degree of simplicity and continunity in handling, all lend their part in successfully carrying out heat treating processes.

The science of heat treating steel has become well established, but the art of heat treating has its many problems ever before us.

Known materials subjected to the best available processes of heat treatment, carefully, conscientiously and persistently executed, should and will produce consistent results.

DISCUSSION

Mr. W. E. Moore:* I would like to ask Mr. Lynch if, after his experience with various methods of quenching, he felt he might not have accomplished the same results with proper arrangements using water quenching, and thus save the expense, danger and nuisance of oil quenching?

Mr. T. D. Lynch: In reply to that, the results of our water hardening of the eight-inch shell showed very clearly that we did get equal results when we allowed the water to get warm. When we had the water too cold, or attempted to spray inside and outside at the same time, we got into trouble because of too rapid cooling; but, allowing the water to become warm, its cooling properties were very much less drastic. We found by some experiments that the quenching speed of water at 40 degrees C. is about equal to that of oil. When the water becomes warmer than that, it seems less drastic than oil, and only about half the speed of oil when the boiling point of water is reached.

Mr. W. E. Moore: I take it, then, that you found no compensating results whatever from oil quenching and that you feel you might have produced equally good or better results with water quenching by following the proper routine.

Mr. T. D. Lynch: I do not think we derived any special benefit from the use of oil.

Mr. C. P. Miller:† I would like to ask Mr. Lynch if he got any results from the impact test in his screw steel tests. He told me he was going to make some tests on that and I have followed some of it in the laboratory at Wilmerding, getting the same tensile strength he did and I made a few impact tests and found that the water quench gave an impact of about 50 per cent. greater, in spite of the fact that the water quenched steel had considerably higher physical properties.

*President, W. E. Moore & Co., Pittsburgh.

†Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Mr. T. D. Lynch: I did not have occasion to work any impact tests on the automatic screw material except that I took a bolt that I had heat treated, sawed it half way through, put it in a vise and hit it with a hammer. The bolt bent over instead of breaking and the fracture was of a fibrous nature. This was open-hearth screw stock, and I make a distinction between the steel with added sulphur and the steel where the sulphur was not added.

Mr. C. P. Miller: The test that I made on the untreated steel was about 50 foot-pounds, while that on the treated steel was about 70. And that was much higher than the results that have been obtained on high-grade chrome-nickel steel. We had to make the tests out at Swissvale, Pa., on air-craft material. We have used a great deal of this screw stock and we have had a great deal of trouble with breaking. Analysis showed that the material was open-hearth steel very low in phosphorus.

Mr. George H. Neilson:* I would like to ask whether the hardening process used on the eight-inch shell in this country was a development of our own, or practically the same as used on the other side by the Allies.

Mr. T. D. Lynch: As I understand it, the practice in France was to quench in water spray and because of this French practice, as I understand it, the Ordnance Department at Washington asked that we do the same on our first orders. But the steel in this country does not seem to be quite the same as it is over there for some reason and we had excessive breakage as long as we attempted quenching in cold water spray. Just as soon as we allowed the water to become warm we made good both in quality of product and freedom from breakage.

Mr. George H. Neilson: Were the analyses of the two steels about the same?

Mr. T. D. Lynch: I do not know. Dr. Unger can probably tell.

*Vice President, Braeburn Steel Co., Braeburn, Pa.

Dr. John S. Unger:* They used a little lower carbon and a little lower manganese.

Mr. T. D. Lynch: That would help very much.

Mr. C. M. Johnson:† I would like to ask Mr. Lynch what was the temperature of the water used to spray the shells—that is, when the treatment proved to be too drastic—was the water cold or was it warmed?

Mr. T. D. Lynch: Cold water.

Mr. C. M. Johnson: What would have been the result had you sprayed with warm water?

Mr. T. D. Lynch: I think we would have obtained very much better results. If we had used water up to the boiling point, we would have had most excellent results. That was one of the processes we wanted to follow but we were not permitted to do so.

Mr. W. E. Moore: I would like to ask Mr. Lynch whether, when using the cold water spray quench, he tried the experiment of taking the steel out of the bath before the steel was entirely cold, and if when so manipulated he did not find that his breakage troubles were eliminated.

Mr. T. D. Lynch: In answer to that question, I would say that our facilities were not such that we could get them in and out quickly enough to accomplish exactly that result. But we did try putting them into the water without the spraying and taking them out before they were cold, and got very good results by that method. This practice was not looked upon favorably by the Ordnance Department.

Mr. George H. Neilson: Was there any record kept of the number of failures that resulted from the hardening process, as far as the subsequent working of the shell was concerned?

*Manager, Central Research Bureau, Carnegie Steel Co., Pittsburgh.

†Director of Research Department, Crucible Steel Co. of America, Pittsburgh.

Mr. T. D. Lynch: Do you mean in service?

Mr. George H. Neilson: Yes. I recently read an article in which it was stated that a great many shell failures were due principally to the hardening process.

Mr. T. D. Lynch: In answer to that—though I can make no authoritative statement—I was told that some of the shell being manufactured in this country were failing. I was immediately interested in knowing whether any of them were ours. I asked the question: "Were these heat-treated shell or untreated shell?" and the answer was that they were untreated shell. The failures referred to were not in service but in special tests at the proving grounds.

Mr. George H. Neilson: Were very many untreated shell bought by the Government?

Mr. T. D. Lynch: A great many were attempted. I do not know how many were shipped.

Mr. W. H. Phillips:* I was very much interested in the Brinell hardness tests. As I understand it, for a certain Brinell hardness you can determine the physical properties, provided the chemical properties were within certain ranges. Would it be possible to work out a formula which would enable us, knowing the composition of the steel and assuming that the heat treatment was the same, to determine the physical properties from the Brinell hardness? Or is it necessary to go still farther into the sections and the temperature above the critical point before we can lay down some formula that will enable us to determine what the physical properties will be, knowing the composition and the Brinell hardness?

Mr. T. D. Lynch: I do not know that my tests would establish a law of that kind; I do not think they would. As I have often told young men that I have had to do with in our

*R. D. Nuttall Co., Pittsburgh.

own plant, it takes a great many tests to make a law, while any one test may decide whether or not it is governed by a certain law. My experience with testing of shell showed very clearly that if we know the carbon and manganese content and know the heat treatment where we are duplicating work, and then make our Brinell tests, we know pretty nearly what the results of our physical tests will be. They are very consistent—more so than anticipated. Yet, if you attempt to vary the heat treatment or make tests without any heat treatment, the results are quite variable and no comparison can be established.

Mr. C. M. Johnson: I assume that Mr. Lynch means, when he states his law for the hardening numeral based on 3C + Mn, that the phosphorus and sulphur contents remain substantially the same.

Mr. T. D. Lynch: Yes, I assume that.

Mr. W. E. Moore: I assume that Mr. Lynch treated shell made both from cast slugs and from slugs forged from rolled bars and I would like to ask if he found any difference in the physical qualities of the shell steel as made from two different types of slug steel.

Mr. T. D. Lynch: Our shell were all made from slugs forged from rolled bars.

CONSTRUCTION OF STEEL BARGES

By Thomas Leach*

HISTORY OF THE ERIE CANAL

I have been asked to outline to you briefly the construction of steel canal barges from the viewpoint of the steel fabricator rather than from the viewpoint of a shipbuilding organization. Before taking up this particular problem, it may be of more or less interest to you to know something of the history of the water route from New York to Buffalo, and particularly that portion embracing the present route of the Erie Canal, which route utilizes to a very considerable extent the natural waterways including the Mohawk River, Oneida Lake, etc.

The original Erie Canal was known as Clinton's Ditch, and parts of it are still in existence. This canal was indeed a ditch and a small one at that, it being but four feet in depth. The original cost amounted to $8 000 000, this cost being defrayed by the state of New York which in turn exacted tolls from the users. These tolls were abolished in 1882, but not until the state had realized a clear profit on the original investment of $8 000 000. This rate over and above the interest on the investment and all operating expenses amounted to $43 000 000.

The original motive power is one with which we are all familiar. These small boats were towed either by man, horse or mule power and the trip from Albany, or rather from Troy where the canal connected with the Hudson River, to Buffalo was a long and tedious one. There were at intervals opportunities for one boat to pass another in a widened section. Nevertheless, in spite of the crude methods employed and the difficulties encountered, the rates of freight between New York and Buffalo, thanks to the canal, were reduced from $22 to $4 a ton; the latter rate comparing very favorably with the freight rate between these two points in the year 1919. This fact appeals to me as being most significant.

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During the 30's and 40's the state of New York undertook what was then considered very extensive railroad construction, and New York and Buffalo were finally connected with a through line. The operation of this road under state management, however, was not a success. In fact it was so much of a failure as practically to go into bankruptcy and it was taken over by private interests.

Shortly after this, in spite of every effort on the part of the railroad interests to prevent it, the original canal was increased to seven feet in depth. This improvement was completed in 1862, and in the first year of its operation something over five million tons of freight were moved through this new canal. Naturally the railroad interests took very active and radical steps to make canal competition impracticable. There being no public service boards and interstate commerce commissions at that time, the railroads went so far as to increase rates very materially during the winter season when the canal was closed and then underbid the canal rates during the season of navigation. It is history in practically every line of endeavor, that privately owned enterprises are progressive, while municipal, state and Government controlled industries are satisfied to proceed along the lines in vogue when these projects were instituted or originally taken over. This condition obtained as between the state and the railroads, the private enterprises forging ahead with marked and continuous improvement, in operation and management, while the canal showed absolutely no change or improvement but on the contrary was allowed to deteriorate.

In 1865 there were 10 000 barges on the Erie Canal actively engaged in the transportation of merchandise of every description. That is to say, in active and successful competition with the New York Central Railroad, which paralleled the waterway the entire length of the state. In 1916 this number was reduced to 300 old-type wooden boats, rapidly deteriorating and but a sorry reminder of the earlier successful activities. Do not understand from this that the state continued with this narrow canal of seven feet in depth, for that is not the case. From time to time the people and the legislature of New York indulged in much agitated and active discussion on the question of enlargement and

improvement of this waterway. In fact there has for years been an Erie Canal accommodating much larger boats with a draft of approximately six feet. The revival of business resulting from this larger canal was but temporary, however, and the canal traffic with wooden boats drawn by mules continued to grow less and less.

In 1903, after much discussion and agitation as between the construction of a ship canal or a barge canal, a law was passed to construct the latter with a depth of 12½ feet. The estimated cost of this canal was $101 000 000. The actual final cost will amount to approximately $154 000 000. This increased cost was, to an extent at least, due to some of the following conditions: Primarily, there was an unprecedented increase in the cost of labor and materials; there was a change in the size of the locks, which were originally specified with a width of 28 feet, which was finally changed to 45 feet; the fixed bridges were changed to lift bridges. It will be realized that the last two items have added materially to the cost when we consider that there are something over 300 bridges crossing the canal, and that there are 57 locks, with a maximum lift of 40½ feet. The construction of the canal provided for a maximum clearance of 15 feet and, in addition to the fixed bridges with the necessary approaches to meet this clearance, there are 86 railroad crossings over the new canal.

At the present time the maximum draft is but 8½ feet. It is anticipated, however, that within the next 12 months this will be increased to 10 feet, there being but a limited number of sections requiring additional dredging or removal of rock. As has already been stated, the maximum clearance is 15 feet. The size of the locks is 310 by 45 feet, which will permit the locking of a barge 300 feet in length by 44 feet in width. The maximum width as just stated is perhaps excessive for the reason that this is governed by the United States Government locks at Troy, New York, which are but 44.4 feet in width.

If the canal is to take a leading part in the carrying of grain, it is apparent that additional elevator capacity suitable to canal needs must be provided in New York harbor. The fact that from 50 000 000 to 100 000 000 bushels of wheat yearly are received in Buffalo, destined for the seaboard, indicates an opportunity on the part of the canal for its transportation. The amount of wheat

received at Buffalo by lake in 1917 reached the enormous total of 94 924 407 bushels, most of this being destined for the seaboard. The canal, furnishing a direct route, should ultimately receive such a proportion of this as will be limited only by the capacity of the carriers suitable for such service.

TYPES OF BOATS AND BARGES

All boats navigating the canal up to the present have been of wood, except one fleet of steel barges which were very successful but which were withdrawn to foreign waters.

All boats navigating the canal must have rounded bows. The use of rectangular shaped barges is forbidden, owing to the fact that they are difficult to manage when passing through the locks. The exact size of barge most suitable for this water is a question on which there is great diversity of opinion. The barges now being built for the United States Railroad Administration are 150 by 20 by 12 feet, with a capacity of 500 dead weight tons on a draft of 8½ feet. They will be operated in fleets of four—one power barge with three consorts. In navigating, the power barge will push one and tow two. The freight carrying capacity of the power barge will be about 400 tons, and four barges can be locked at one time. A detailed description of these barges will be given later.

The largest type of boat seriously suggested is 250 feet long, with a 35- to 40-foot beam, with a 12-foot molded depth and a carrying capacity of about 2500 tons. This boat has been suggested for carrying merchandise or packet freight between cities on the canal. This may be a steam- or oil-driven barge carrying a deck load. This size of boat has the advantage of being adapted to use in a warmer climate during the closed season of navigation.

BARGES FOR UNITED STATES RAILROAD ADMINISTRATION

The United States Government has placed under contract the building of 75 barges, 150 feet long and from 20 feet to 21 feet

Fig. 1. Plan and Section of 150-Ton Steel Barge.

4 inches in width and designed to have a cargo capacity of from 500 to 700 tons. Of these barges, 51 are to be of steel and the remainder of concrete. In addition to the above, contracts were placed for 20 steam propelled cargo barges of steel construction, which will be described and illustrated later.

The steel cargo barges (See Fig. 1) under construction for the Erie Canal are constructed throughout of steel, having a length inside fenders of 150 feet, a molded breadth of 20 feet and a molded depth of 12 feet, with a cargo carrying capacity of approximately 500 tons. Four transverse bulkheads divide the hull into five water-tight compartments. Each cargo hold is served by two hatches, 10 by 14 feet. Accommodation for the crew is provided for in the house at the after end. The ends are spoon shape, with flat bilge carried on the round up to bottom.

The dimensions of framing and method of construction are shown in the cross section (See Fig. 1). The shell plating is 13 pounds per square foot. All seams are single riveted and the butts double chain riveted with ⅝-inch countersunk flush rivets. Rivets connecting the shell plating to the frames are spaced seven diameters apart.

Water-tight bulkheads (See Fig. 2) are built of 12-pound plate with vertical seams, having 3-inch by 3-inch angle stiffeners, spaced 24 inches apart at the center and 18 inches at the sides. The bounding bars connecting the bulkheads to the shell plating are 3-inch by 3-inch angles with ⅝-inch rivets spaced four diameters. A horizontal stiffener is riveted to the bulkhead at the floor level to take the ends of the hold ceiling.

Fig. 2. Steel Cargo Barge for Erie Canal. Bulkhead Details.

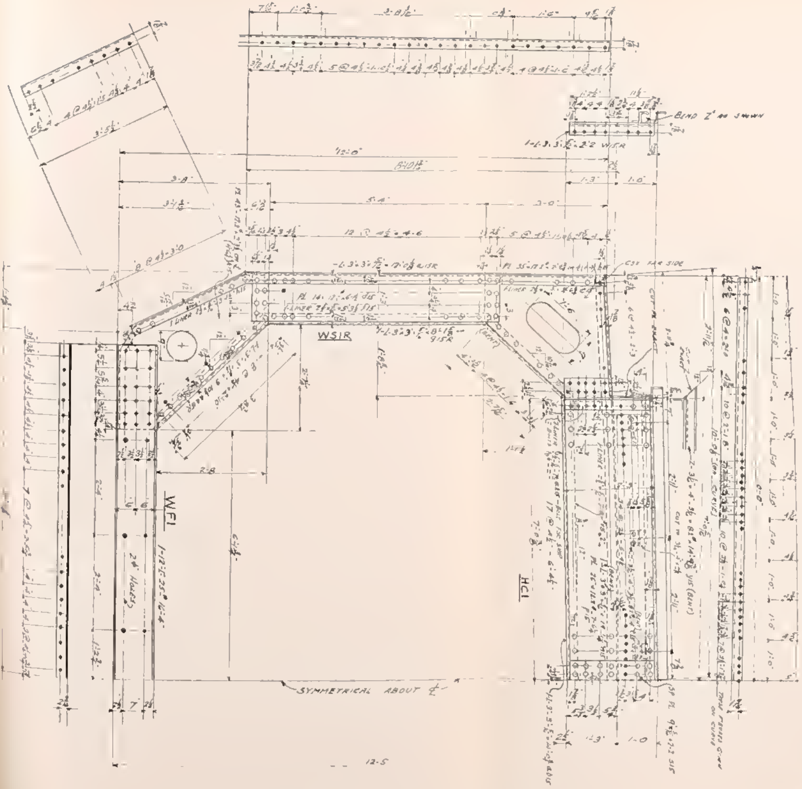


Fig. 3. Steel Cargo Barge for Erie Canal. Web-Frame Details.

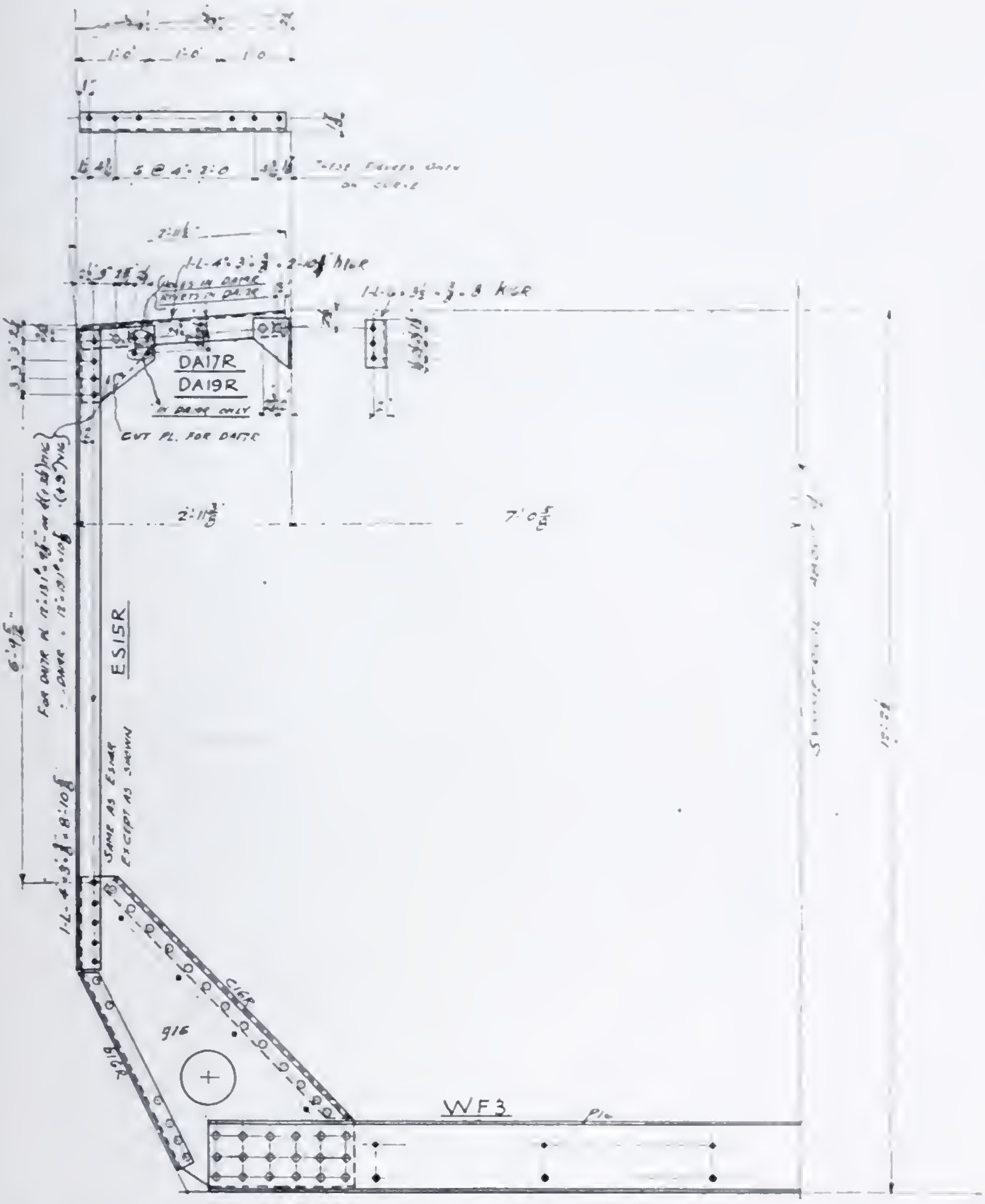


Fig. 4. Steel Cargo Barge for Erie Canal. Intermediate Frame Details.

The framing (See Fig. 3–6) consists of 4-inch by 3-inch by 8.5-pound angles, spaced 24 inches apart. The web frames are 15 inches deep, constructed of 3-inch by 3-inch angles and 12-pound plates; one fitted at the end of each hatch. The floors consist of 12-inch, 25-pound channels connected to the side frames bilge by 3-inch by 3-inch angles. Through deck beams are 5-inch by 3-inch angles, connected to frames by 12-inch brackets. Short beams are 4-inch by 3-inch angles, connected to hatch coamings by 6-inch by 3½-inch angle brackets. The deck camber is five inches.

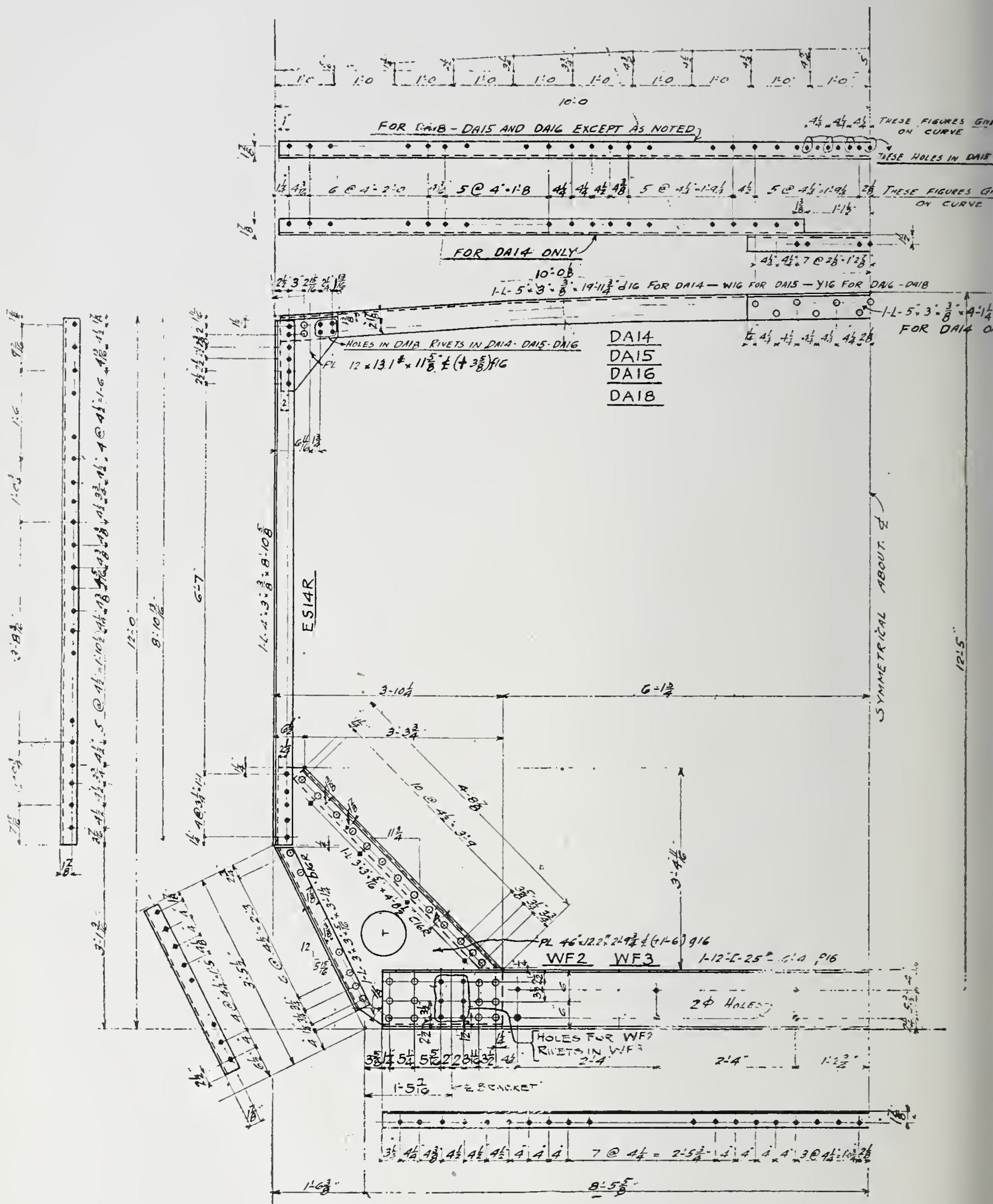


Fig. 5. Steel Cargo Barge for Erie Canal. Intermediate Frame Details.

The hatch coamings are built of 12-pound plate, 12 inches above the deck at the sides, extending 15 inches below deck, connected to the deck by a 3-inch by 3-inch angle. The top edge is fitted with 4-foot by 3-inch Z-bars to form the hatch ledge. The hatch covers are wood, 2¾ inches thick with flush lifting

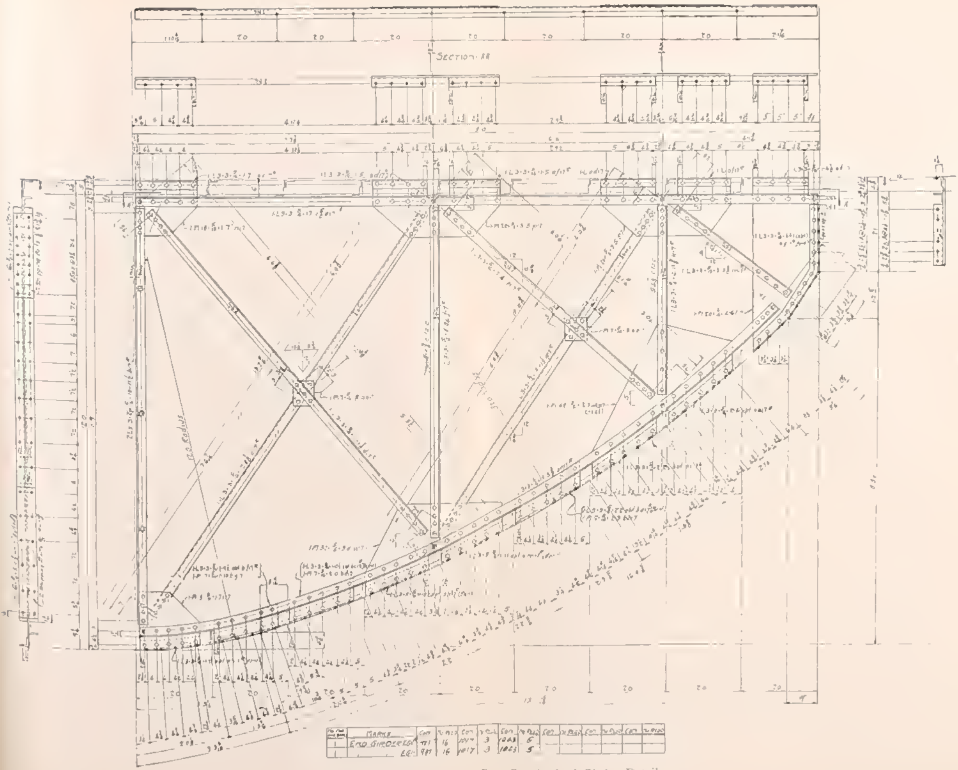


Fig. 6. Steel Cargo Barge for Erie Canal. End Girder Details.

rings at each end. Heavy canvas tarpaulins are used with battens and wedges for securing them.

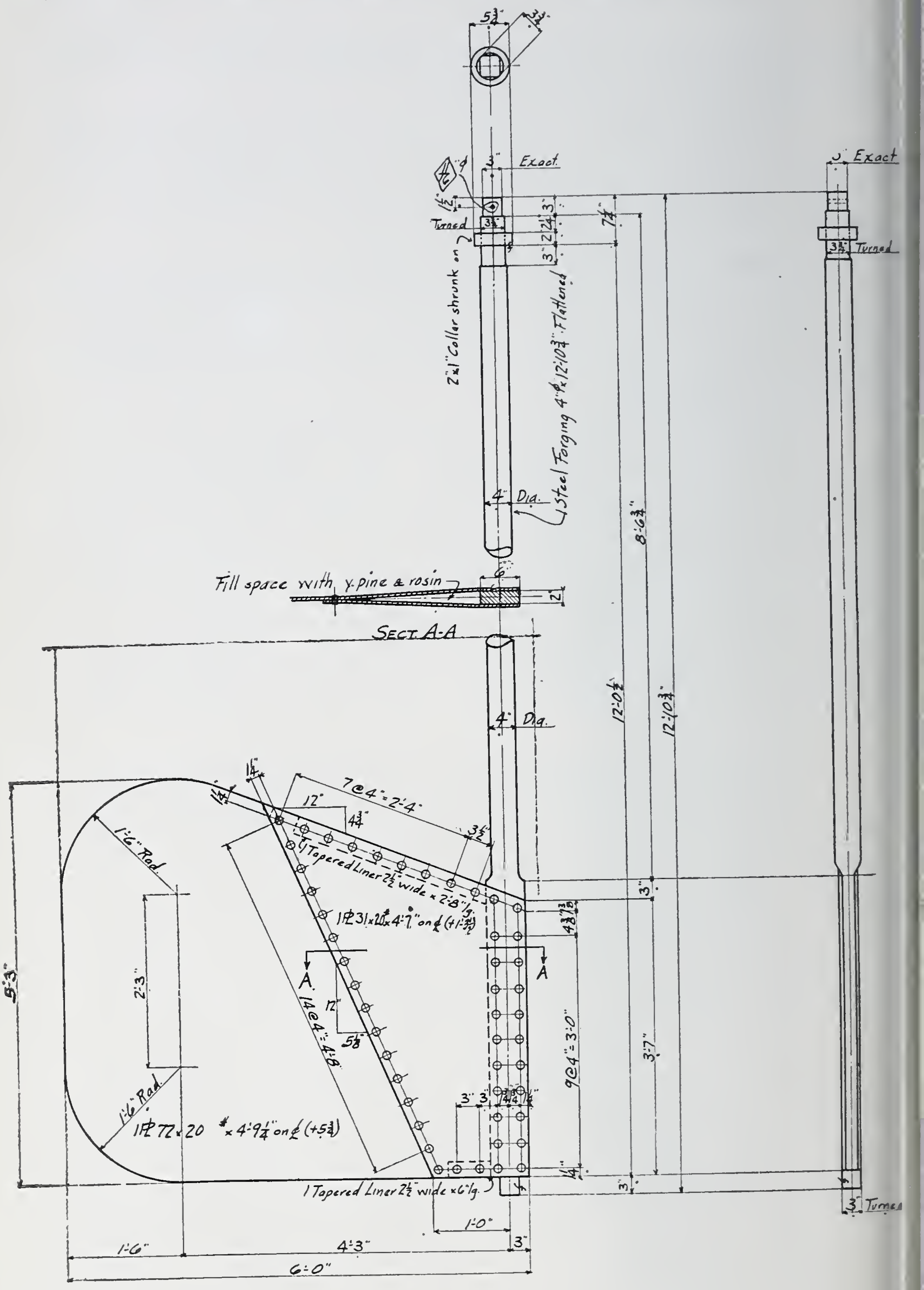
There are three oak fenders, fitted six by nine inches and secured to the shell plating by 3-inch by 3-inch angles and faced with 6- by ½-inch flat steel. The top fender is carried across the ends and increased in depth to 21 inches.

A rudder skeg built of 18-pound plating is connected to the after end of the hull with double angles and forged steel struts or braces. The lower edge is fitted with a cast-steel gudgeon, bored and fitted with bronze, and fitted with a bronze bushing to take the rudder pintle.

The holds are ceiled with 2- by 12-inch planking and carried up to the top of the bilge brackets. The deck-house aft, constructed of wood, projects three feet six inches above deck, with companion hatch and stairs opening aft. The interior is fitted with two berths, lavatory with pump, galley sink with brass pump, one "two-hole" Shipmate range, an oak table, dish racks, etc. A large locker is built in one corner, and the pump water closet enclosure is on the opposite side. The floor is covered with linoleum.

The rudder (See Fig. 7) is of steel plate, with a forged steel stock four inches in diameter, having a water-tight rudder well extending from the bottom of the barge to the deck, with a brass-bushed rudder carrier to take the weight of the rudder. The stock is finished square on top to take a forged steel tiller to which are attached tiller ropes leading through quarter blocks to the steering gear (See Fig. 8–9), which is of the geared drum type with a four-foot wheel located aft of the deck-house.

A 400-pound stockless anchor, with davit for handling same, is fitted on the forward end; also a pump-brake windlass with wildcat and gipsy head; all necessary towing and mooring bollards; cleats; fair-leads; refrigerator; fresh-water tanks; life pumps with portable rods and buckets, two for each hold; hatches, with suitable ladders to each hold; navigating lights; railing and stanchions—all as indicated on the plan, with equipment as called for by the United States regulations. Details of certain deck fittings are shown in Fig. 10–11.



RUDDER R1

Fig. 7. Steel Cargo Barge for Erie Canal. Rudder.

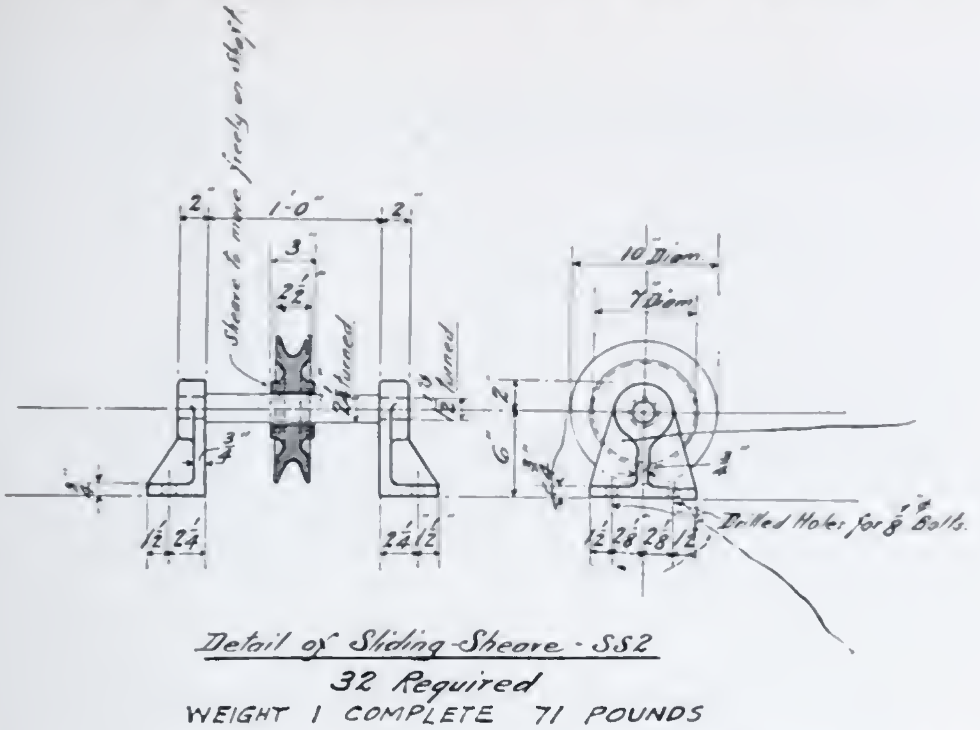


Fig. 8. Steel Cargo Barge for Erie Canal. Steering and Towing Arrangement.

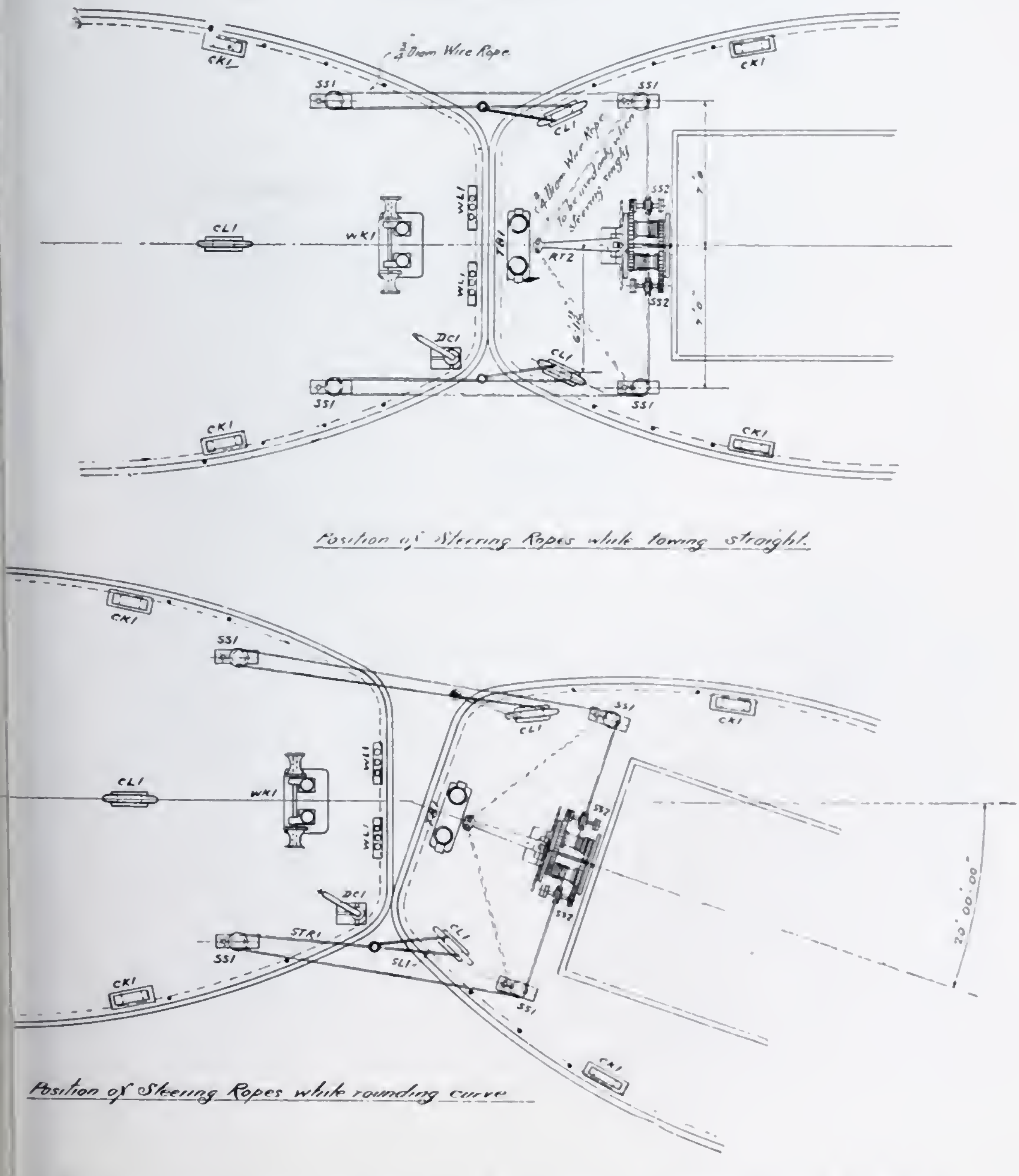


Fig. 9. Steel Cargo Barge for Erie Canal. Steering and Towing Arrangement.

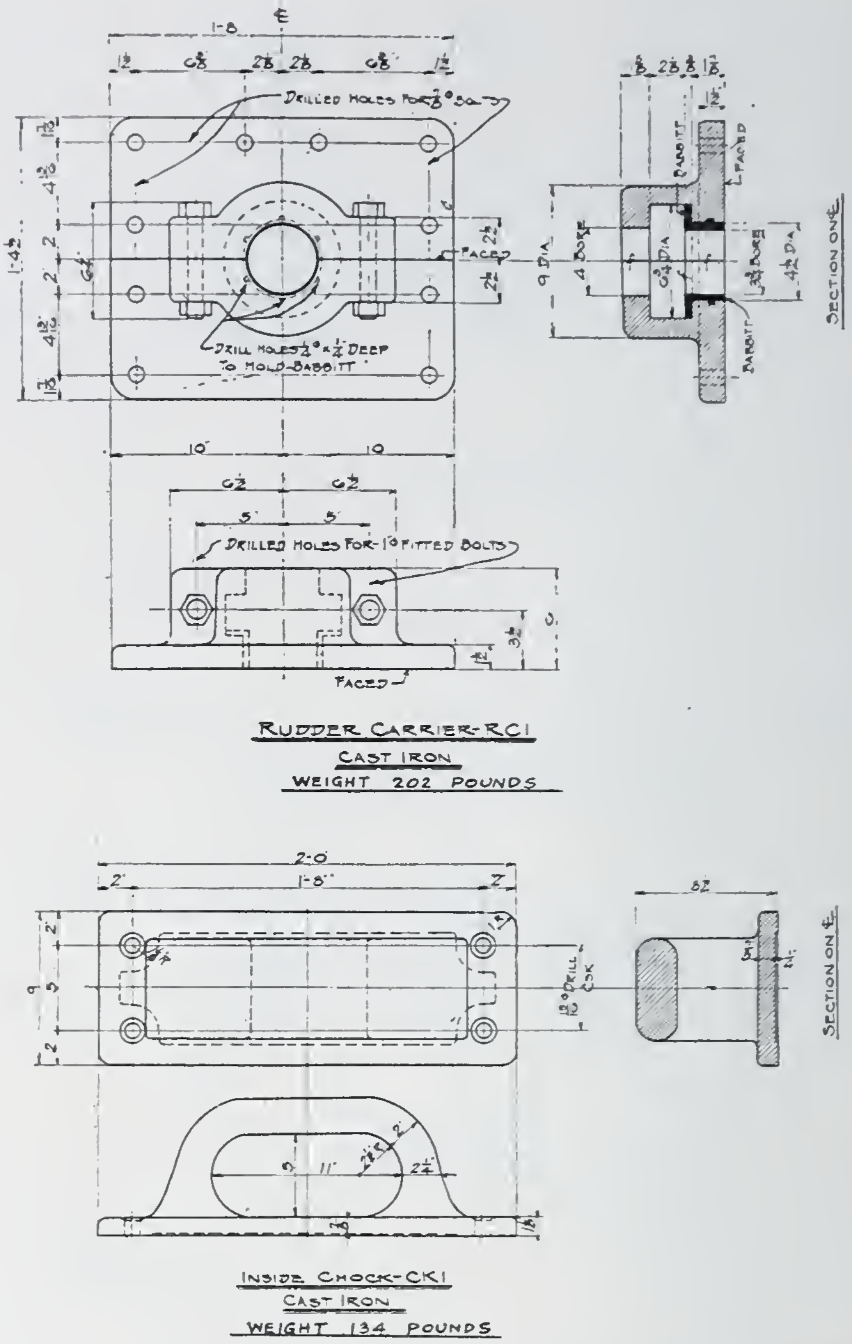


Fig. 10. Steel Cargo Barge for Erie Canal. Deck Fittings.

Our first venture on barge work was in the spring of 1918 when we secured a contract for 16 barges complete, and additional contracts for fabrication only of eight more barges from the same drawings. At that time we had not done any shipbuilding work and these barges were fabricated entirely as a structural job. There were 45 detail drawings which were made by our regular force of structural draftsmen and although they were detailed so that full advantage might be taken of a multiple punch, with a Thomas spacer—which was ordered, but not installed in time to do any work on this contract—we surmounted that difficulty by rigging up a spacer and attaching it to a Long & Allstatter 18-hole beam punch. In construing this impro-

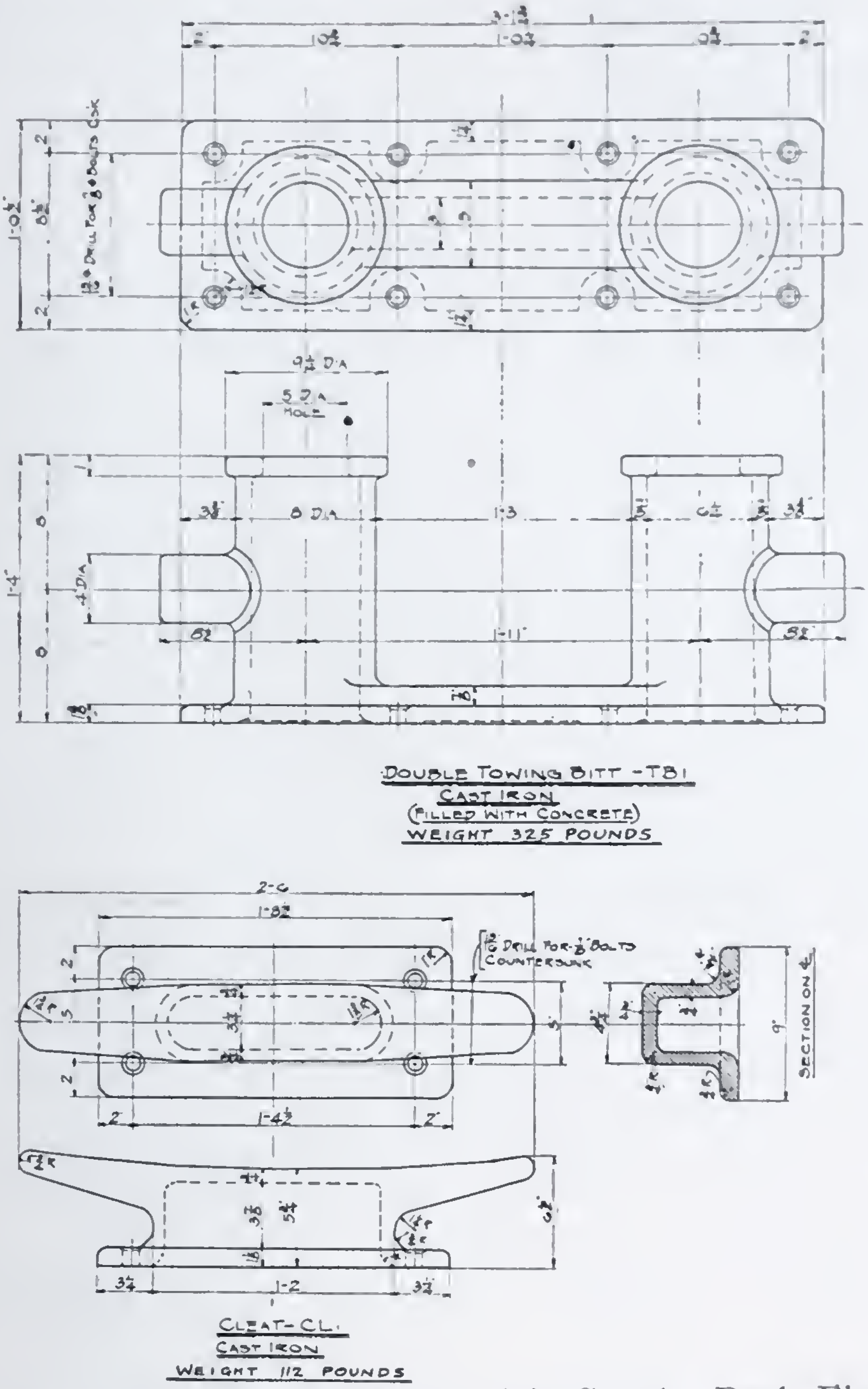


Fig. 11. Steel Cargo Barge for Erie Canal. Deck Fittings.

vised spacer, we built a carriage to run on two I-beams laid on the ground. On one of these I-beams we laid a wooden templet and attached to the carriage a pointed finger which ran very close to the templet. This was operated by hand and the accuracy with which it worked was amazing, for the machine was very roughly constructed; in fact, it was built entirely without drawings. Even the hand-wheel was burned out of a 24 by ¼ plate with a few rods bolted on for handles. This enabled us to utilize our beam punch and greatly increased our punching capacity. Nearly all plates were punched on this machine, except plates with irregular spacing which were punched on a single punch utilizing a Lysholm table.

There were approximately 120 000 holes per barge. During fabrication we made what we believe to be a record for punching. On a single punch with a Connely spacer we punched 18 624 holes in a 10-hour day.

Experiments were made on punching countersunk holes in shell plates, but this method was not used on the above job, due to objections from the inspector. In our opinion such punching is quite satisfactory where such thin plates are used. The curved ends were not detailed in the drawing room but a full sized model of half of one end was made in the templet shop. From this, templets were made for all curved work, and this method proved very satisfactory. There were some plates which needed furnace work with very difficult bends. These, however, were bent quite satisfactorily from templets made from the model, as was very clearly demonstrated during assembling, the only field work necessary being the drilling of four holes per barge.

There are 14 330 shop rivets and 38 570 field rivets, making a total of 52 900 rivets to each barge.

All frames and bulkheads were completely riveted in the shop and transferred to the assembly yard on railroad cars. In each barge there are 6530 linear feet of seams to calk. The total weight of structural steel per barge is 136.8 tons, of which 87 tons are plates; 28 tons, angles; 11 tons, channels; and the remainder, rivets and details. No plate edges were planed.

SELF PROPELLED STEEL CARGO BARGES FOR THE NEW YORK STATE BARGE CANAL, DESIGNED BY COX & STEVENS FOR THE UNITED STATES RAILROAD ADMINISTRATION

This barge (See Fig. 12) is of the same general dimensions as the tow barge, but there are certain variations in construction. The deck stringers, shear strake, and heel-plate are increased from 5/16 to 3/8 inch in thickness. The bow construction is the same. Between No. 1 bulkhead and No. 1 hold, a sunken deck-house, with accommodations for eight men, is provided, and is fitted with plumbing fixtures, sink, galley and mess room, similar to those of the tow barges. Under the deck-house floor are a feed-water tank and a store-room. Amidships is a steel pilot-house

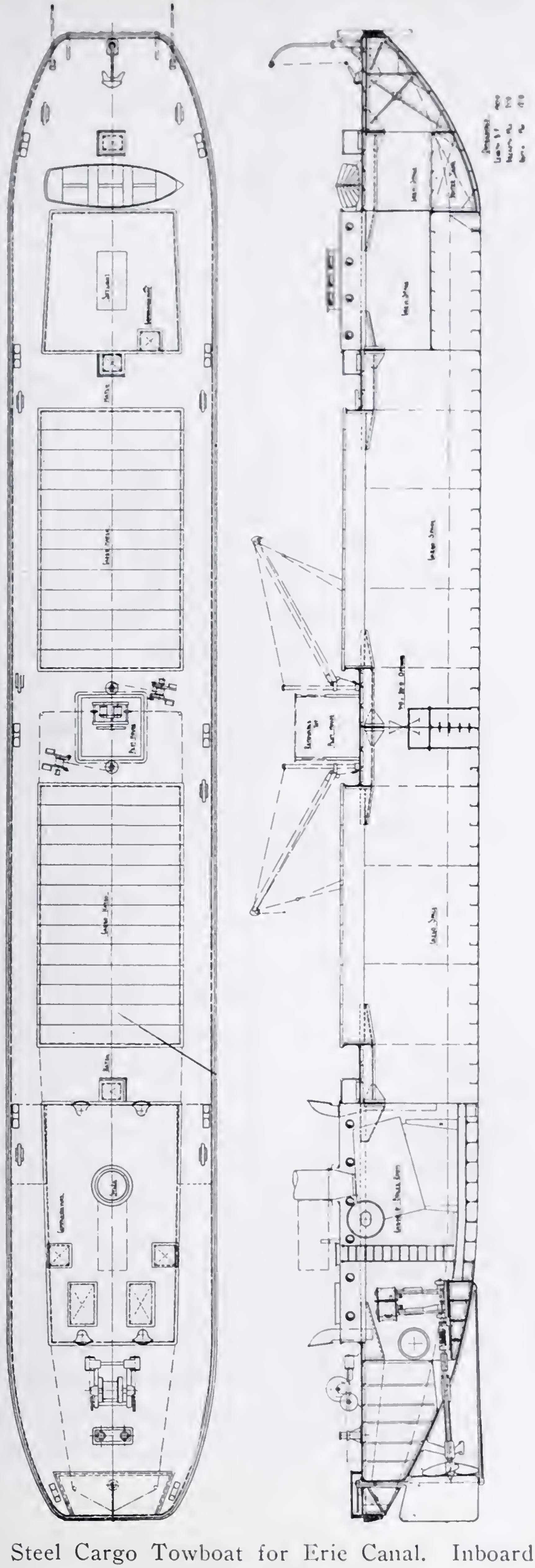


Fig. 12. Steel Cargo Towboat for Erie Canal. Inboard Profile and Deck Plan.

with a wooden top, fitted with Gillie type hand steering-gear with leads alongside the hatches leading aft to the tiller. Communication with the engine-room is maintained by means of a Cory mechanical engine-room telegraph, speaking-tubes and a steam whistle. The propeller is six feet in diameter. In front of the pilot-house are fitted two portable steel derricks, each fitted with a 3 by 4 steam winch having a capacity of 500 pounds on a single whip.

There are three holds. No. 1 and No. 3 are 18 feet in length, each provided with single hatch. No. 2 is 38 feet in length and provided with two hatches. Aft of No. 3 hatch is the machinery space, which has additional stiffening consisting of increased depth of floors and intercostals. A steel trunk about two feet in height, with skylight, is fitted over the engine and boiler. The fuel oil tank is located aft of the engine-room. The deck equipment is the same as that of the tow barges, with the addition of a mooring machine to be used for towing purposes. This is located on the deck and has a single drum and double cylinders, 8 by 10 inches.

Each hold is fitted with a 4-inch stand-pipe arranged with a tee head and a plug for sounding, on the side of which is connected a 4-inch siphon to be used for draining holds in an emergency.

The propelling machinery consists of a water-tube boiler of approximately 1600 square feet heating surface, arranged for oil burning; with oil pumps, heaters and strainers, using the White system of fuel oil burning. The stack is hinged at the deck to allow for passage under bridges. A forced-draft fan is fitted to the boiler to provide efficient control for the oil burning. The boilers are designed for a working pressure of 225 pounds to the square inch, and are fitted from the after end. The engines are twin screw, each engine being a fore-and-aft compound, 10 by 24 by 14-inch stroke, fitted with Joy valve-gear. The engines are arranged to operate at 200 r.p.m., both engines turning outboard. The auxiliary equipment includes a surface condenser with a cooling surface of about 800 square feet.

There is an independent circulating pump, with eight-inch suction, arranged to draw from both sides of the vessel; with a

four-inch barrel leading to the bilge, and a six-inch discharge to the condenser and driven by a six by six-inch steam-engine.

An independent air-pump of the vertical twin-beam type is installed. Steam cylinder six-inch. Air cylinders one by eight-inch stroke. The air-pump discharges into a combined hot-well and filtering tank with automatic float control operating a vertical simplex feed pump, 7½ by 5 by 10. The fire and bilge pump is a vertical duplex, with two suctions in each hold and one suction in the other compartment, which can also be used as an auxiliary feed pump in addition to which a two-inch injector is fitted for boiler feeding. The feed-water passes through a feed-water heater having a capacity of 10 000 pounds of steam per hour, with a feed-water temperature of 10 degrees F. A small hand-pump is fitted on the deck with a suction to the fresh-water manifold. All living quarters are steam heated.

Electric light is furnished by a direct-connected generating set of 4½-kilowatt capacity, driven by a gasoline engine. This unit furnishes lights for all living quarters and for navigating purposes. The voltage is 110.

The carrying capacity of this barge is about 400 tons, and the weight of the plates, shapes and rivets is 150 tons. The contract price was about $90 000.

DESCRIPTION OF 132-FOOT BARGE

A somewhat similar barge, shown in Fig. 13–14, has a length inside fenders of 132 feet, a molded beam of 20 feet 4 inches and a molded depth of 12 feet. In a general way the construction of this vessel is similar to that of the 150-foot barge, but a closer scrutiny of the drawings will show that its design is more favorable for fabrication in a structural steel shop. The bilge brackets throughout and the web frames and strong beams are 12-inch by 20½-pound channels, while the intermediate frames and deck beams consists of 4-inch by 3-inch by ⅜-inch angles.

It should be evident that a large part of the shapes used in the building of this barge can easily be interchangeable, and since the shell plates can also be made interchangeable within their own strakes, we have the feature of duplication of members, which is

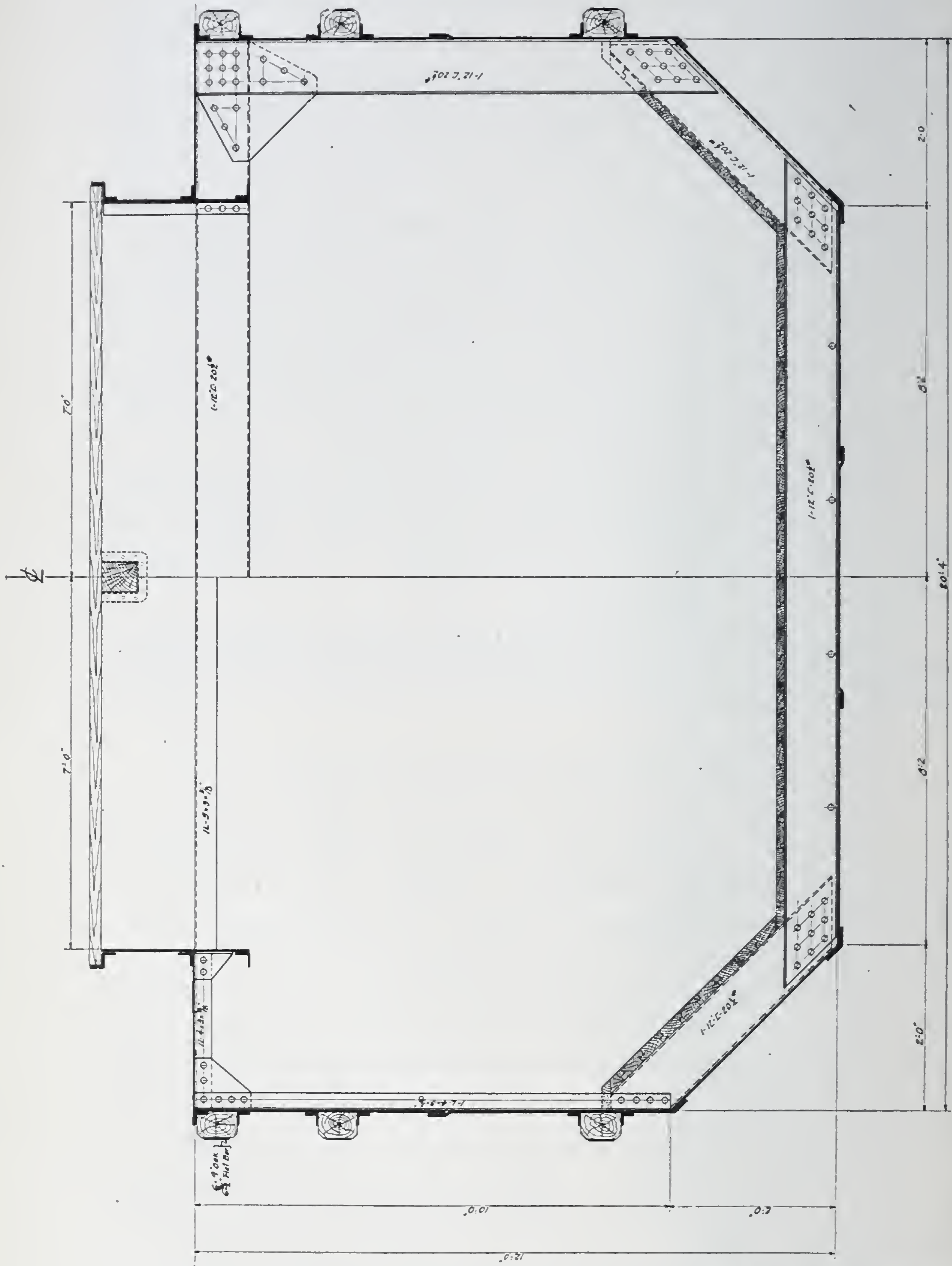


Fig. 13. Proposed Standard 132-Foot Barge. Midship Section.

Fig. 14. Proposed Standard 132-Foot Barge. General Arrangement.

of considerable advantage both to the fabricator and the erector. Furthermore, the ends of this barge are designed with flat surfaces, the necessary curvature of the corners being provided for by widening and rounding the wood fender.

An operating feature, as well as a construction feature of this barge, is the continuous hatch opening. This obviates much of the fine work necessary at hatch corners, and reduces the amount of steel in so far as the intermediate transverse hatch coamings and the decking between the hatches are omitted. The principal advantage of this large hatchway is, however, in the operation of the barge. In general, the larger the total hatch area of a vessel, the more economically can the cargo be handled; and this is especially true in the case of grain handling, as the elevator legs may be moved almost anywhere in this long hatchway without the necessity of moving the barge.

Three bulkheads are fitted in this barge, one at either end, and one at the middle, and three wood fenders are provided. The details of the steering-gear, the crew accommodations, etc., are very similar to those already described for the 150-foot barge.

The steel needed for the construction of this barge amounts to about 106 tons, of which about 64.5 tons are plates; 33.2 tons, shapes; and the remaining 8.3 tons, details. There are about 9100 shop rivets and 29 900 field rivets, or a total of 39 000 rivets to each barge.

DESCRIPTION OF 132-FOOT POWER BARGE

In connection with the 150-foot barge, it was pointed out that these vessels are operated in fleets of four, one of the four being a power barge towing three consorts. Fig. 15 shows the changes made necessary by the installation of a power plant, consisting of two 80-horse-power motors. To provide room for the machinery, the barge is lengthened four feet, giving that amount of additional space abaft the end bulkhead without shortening the cargo holds, and a casing is erected over the engine-room. This casing simply consists of coamings all around, with a steel top, and it is fitted with a companionway for access. The necessary foundations, both for the engines and the fuel oil tanks and gravity

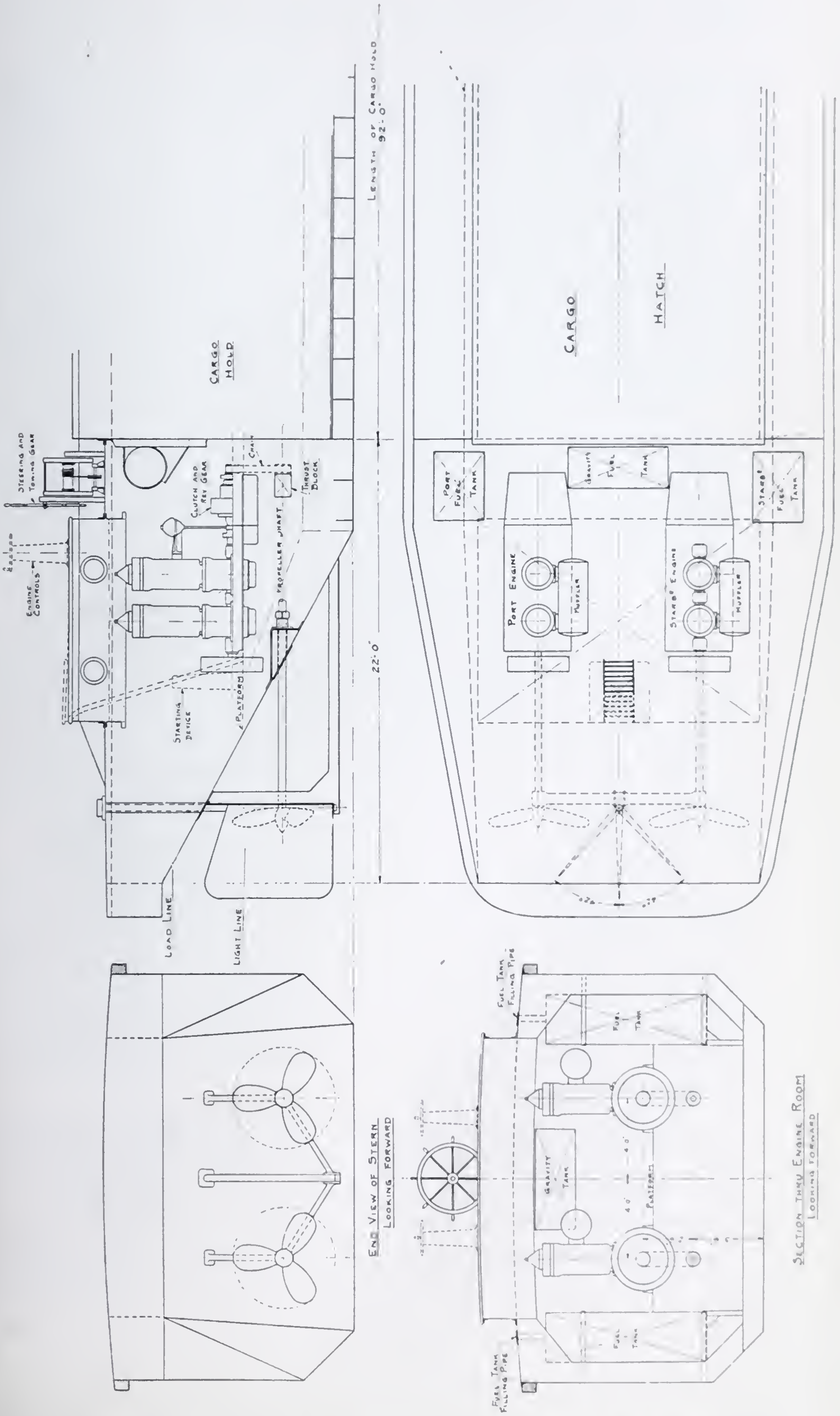


Fig. 15. Proposed Engine-Room Arrangement of 132-Foot Power Barge.

tanks, constitute, of course, a further addition to the steel work.

The installation here shown has the engines installed directly above the propeller shafts, a chain transmission being used. The engines are reversed; that is, the clutch-and-reverse-gear ends which ordinarily would be aft, here point forward; and the propeller shafts, stuffing boxes, and thrust-blocks are below the engine beds, instead of being lined up with the crank-shafts. It will be seen from the figure that if these engines were installed in the ordinary manner, they would project several feet further forward, causing a considerable sacrifice of cargo space.

The cost of this power plant will, of course, depend on the engines selected. With two 80-horse-power motors the whole equipment, including tanks, propellers, etc., could be installed for approximately $13 500, while with more expensive machinery the cost might easily approach twice that figure.

DESCRIPTION OF DOUBLE-ENDED TUG

As an alternative arrangement to the power barge and consorts, we may mention the independent towboat (See Fig. 16). We have here the advantages of greater power, of facility of reversing the direction of propulsion without loss of efficiency and without waste of time in turning the vessel around, and, further, the advantage of not having the power equipment subject to the delays incident to the loading and unloading of a power barge.

It will be seen that the construction of this vessel is very simple, especially if compared with the ocean-going or harbor types of tugboats. The flat surface construction of the barge just described is retained, but the V-bottom is adopted to give sufficient draft for the four-foot propellers, without an undue amount of ballasting. In order to get fairer water to the propeller, the V-principle is also used for the under-water portion of the ends, as shown in the figure.

The power plant consists of a 240-horse-power, reversible motor, operating both propellers on a single, continuous shaft. The fuel oil tanks have a combined capacity of 3500 gallons, or a sufficient quantity for 10 days' run, of 24 hours a day.

To facilitate maneuvering in either direction, two rudders are fitted, each being operated by an independent steering wheel

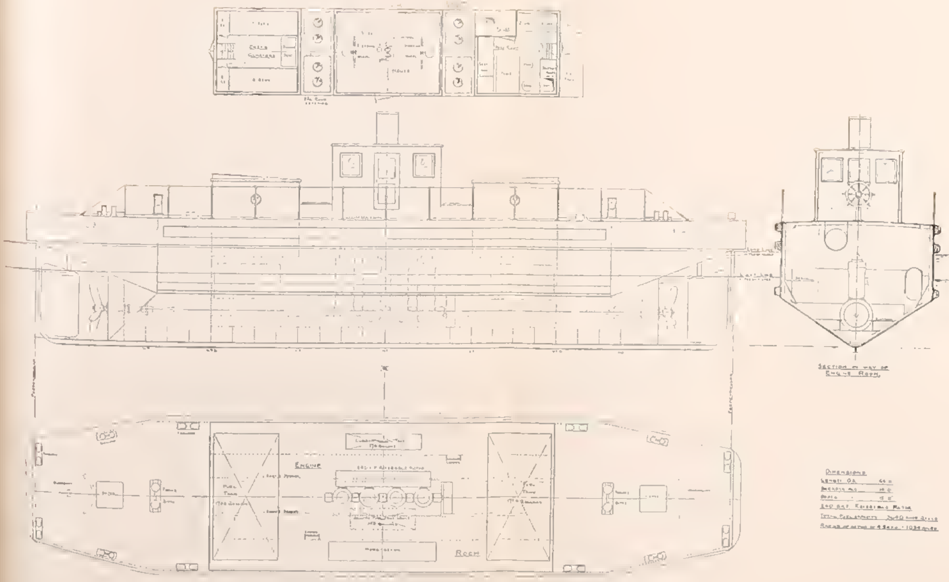


Fig. 16. Proposed Double-Ended Tug. General Arrangement.

through an independent set of leads. Each rudder is provided with a centering device, so that when it is not in use—that is, when it is "forward"—it is held firmly at the center-line of the vessel, where it will cause the least interference with maneuvering by means of the other (aft) rudder. As shown, both steering wheels are located in the wheel-house amidships and between the two wheels a motor control is installed, so that the vessel may be operated from the wheel-house by one man.

Accommodations for the crew are provided in two deck-houses being erected toward either end from the wheel-house. One of these deck-houses provides sleeping room for four men, while the other is fitted up as a mess room, galley, etc.

DESCRIPTION OF 500-TON STEEL BARGE FOR COAL

For cargoes, such as coal or ore, which will not suffer when exposed to the weather, a barge in which the freight is carried on the deck (See Fig. 17) can be used more economically than where the cargo is carried inside of the vessel, and protected by hatch covers. This barge can be almost entirely unloaded by grab-buckets, very little hand shoveling being necessary; and, in loading, the ordinary coal-chute can, of course, be used to the best advantage.

As a retaining wall for the cargo, a bulwark is built all around that part of the deck which is intended to carry the load, a sufficient clear space being left along either side of the vessel to allow passage, and the ends being left clear to permit unobstructed steering and handling of lines, etc. This bulwark is of very simple construction, being built of wooden planking supported by steel brackets. Aside from the addition of the bulwark and the omission of the cargo hatches, it will be noted that this barge differs from the 500-ton freight barge, previously described, in the addition of a lattice girder along the center-line. It seems superfluous to explain that the purpose of this girder is to furnish an intermediate reaction for the deck-beams, thus reducing not only the size of the beams, but also the size of the side frames and the connecting brackets. These changes do not necessitate any alterations in the shell, nor in the construction of the ends of the barge; and the accommodations for the crew, the arrangement

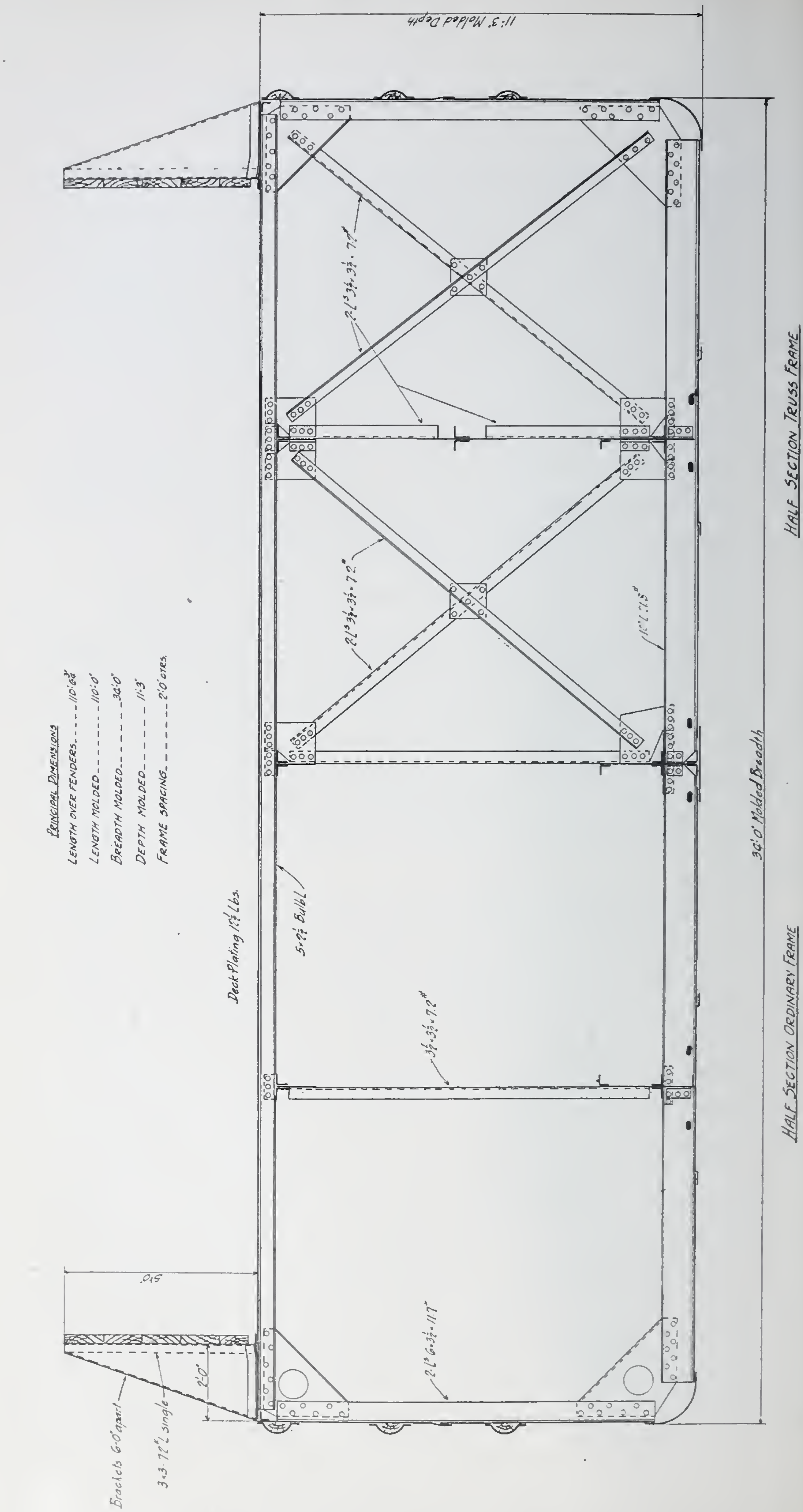


Fig. 17. Midship Section of 500-Ton Steel Barge, for Coal.

and details of steering-gear, etc., can remain practically the same A change is, however, shown in the construction of the fender. Instead of the wood fender, connected to the shell by means of two angles and protected by a flat-bar chafing piece, we have here a corrugated-plate fender. The latter construction is undoubtedly more durable, but it is objected to on account of its lower elasticity. Assuming that the corrugated section is obtainable, the adoption of either type of fender is a matter of personal opinion and has no connection with the change in the type of barge.

To build this barge, 176.3 tons of steel are needed—102.2 tons of plates, 31.1 tons of angles, 27.9 tons of bars and miscellaneous shapes, 5.6 tons of corrugated plates for fenders, and 9.5 tons of rivets.

DESCRIPTION OF 150-FOOT STEEL RIVER BARGE

Fig. 18 shows a barge designed for service on South American rivers. Although of more than twice the cargo capacity, it is very similar both in construction and general arrangement to the 150- by 20- by 12-foot Erie Canal barges.

As in the former case, this barge is divided into two end compartments and three cargo holds by four water-tight bulkheads, and each cargo hold is provided with two cargo hatches. The framing consists of channel floor with built up web-frames and angle intermediate frames and deck-beams.

Owing to the increased width of this barge, a girder is run on top of the floors and under the deck between hatches (except in way of the bulkheads), and one stanchion is fitted in the middle of each cargo hold.

For the accommodation of the crew, a deck-house is erected at each end. Beds for eight men, lockers, a store-room, etc., are provided in the forward deck-house, and the after house is fitted up as a mess room and galley.

To build a barge of this type, there would be required, 120 tons of plates, 41 tons of angles, 16 tons of channels and about 17 tons of rivets and details. About 21 000 shop rivets and 56 400 field rivets would be driven, giving a total of 77 400 rivets.

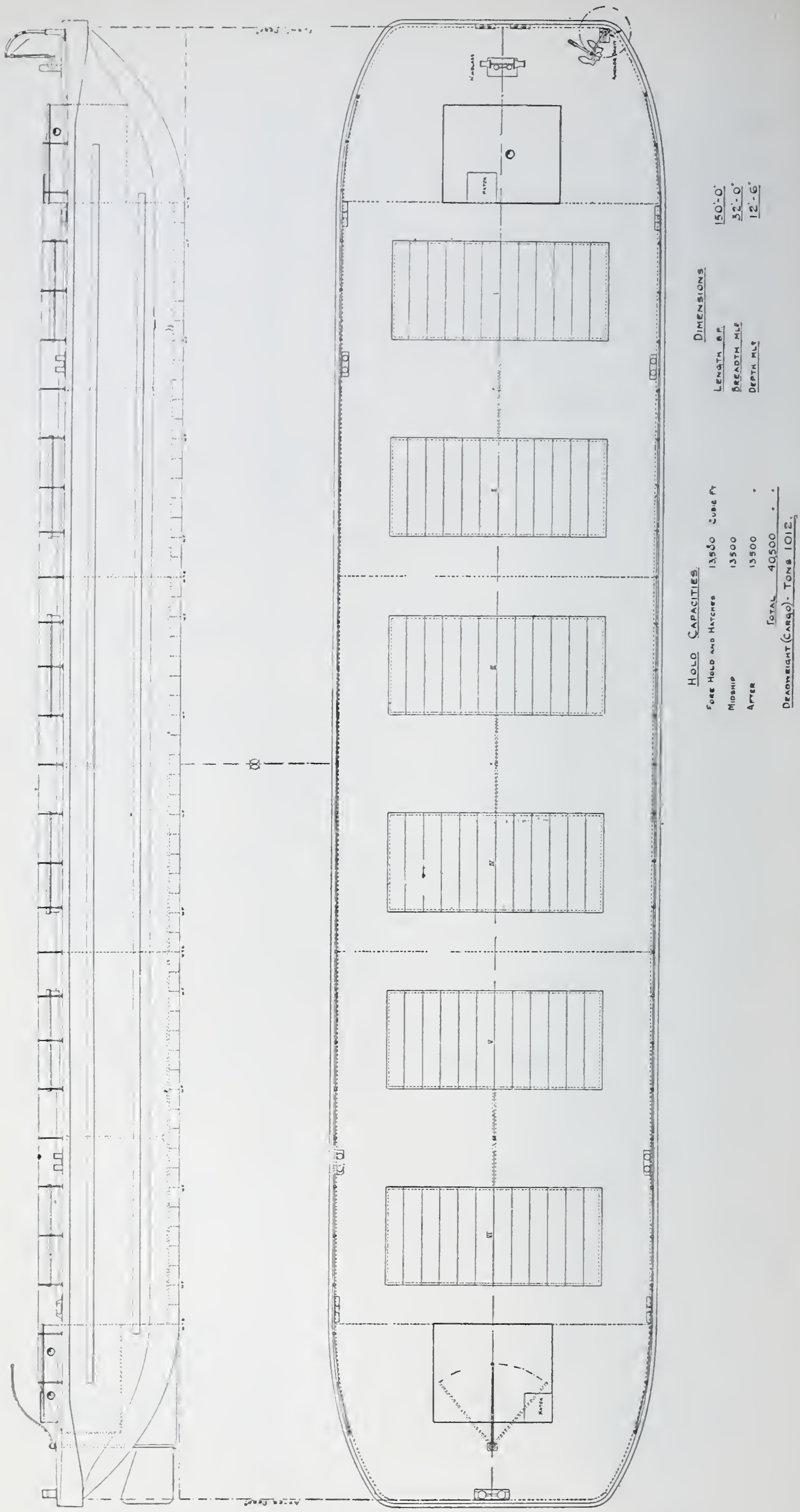


Fig. 18. General Arrangement of 150-Foot Steel River Barge.

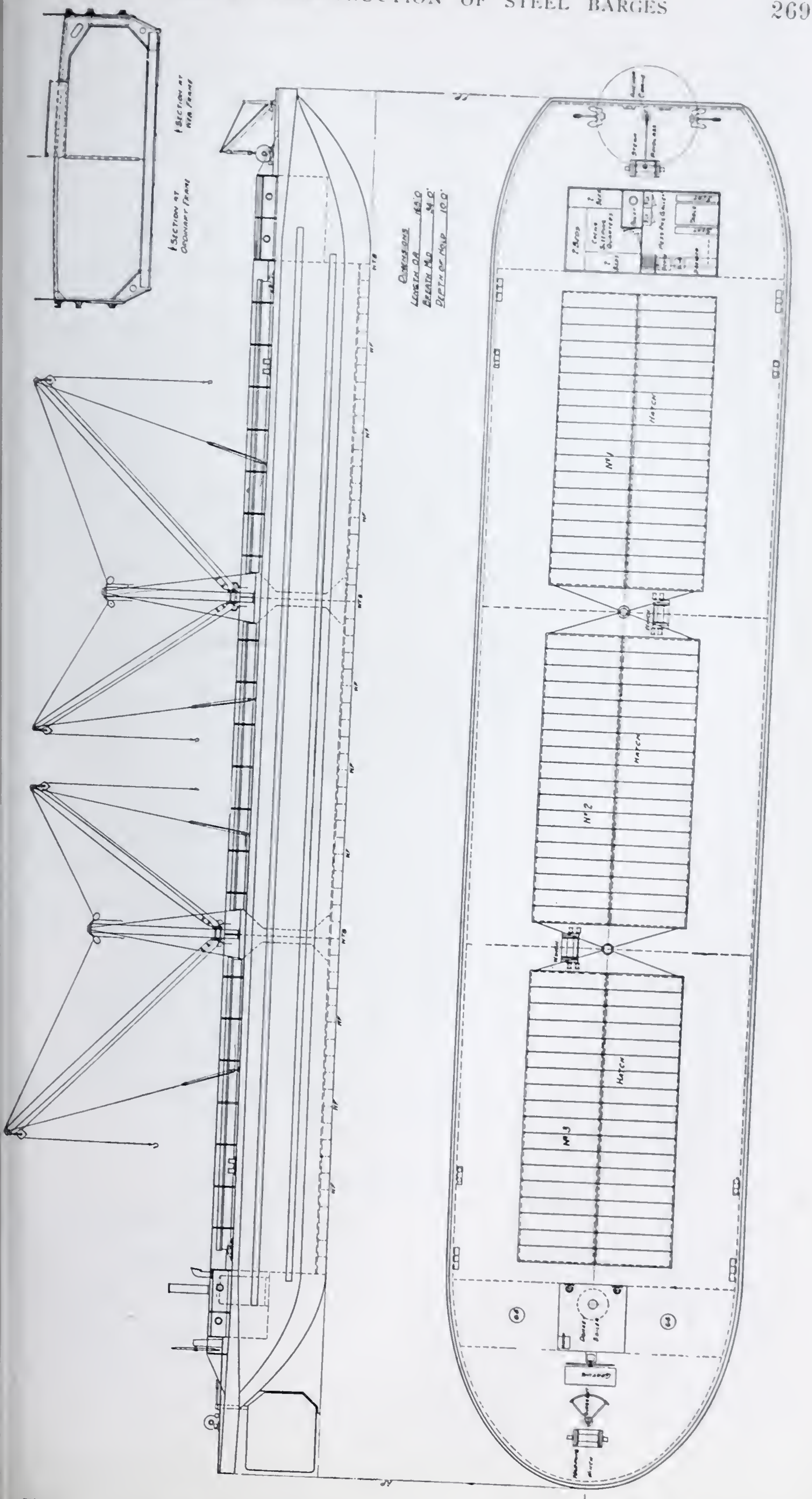


Fig. 19. General Arrangement of 165-Foot Steel River Barge

DESCRIPTION OF 165-FOOT STEEL RIVER BARGE

Another barge designed for South American river service is shown in Fig. 19. Although in appearance this vessel is very different from the one just described, the shell and framing construction are, in fact, very similar for the two vessels, except in so far as the stern end and hatch arrangement are concerned.

In order to make maneuvering possible in the swift currents of the South American rivers, a large rudder is necessary. A rudder of sufficient size could not be fitted under the stern end of the barge, where it would be well protected, and hence a "fan-tail" stern is built out over the rudder. To reduce the power required to operate this large rudder, it is made of the semi-balanced type; that is, a part of the rudder area is forward of the rudder stock.

Each of the three cargo holds of this vessel is served by one large hatch, just enough deck space being allowed between the hatches to provide room for the winches and derrick posts. These derricks are intended to make the barge at least to some degree independent of modern terminal facilities. As is shown, two booms swing over the midship hatch, while the forward and aft hatches are served by one boom each. The hoisting power is furnished by two small steam winches, one of which is located at each derrick post. The necessary steam for these winches and for the steam-driven windlass, is furnished by a donkey boiler installed in a boiler room at the after end of the vessel.

Quarters with accomodations for six men, including mess room, etc., are provided in a deck-house at the forward end.

Fig. 20 shows the method of launching barges at the works of the Ferguson Steel & Iron Company, Buffalo.

NOTES ON FABRICATED BARGES

For several years past, barges of the last two types describe have been fabricated in Great Britain and shipped in a knock down condition to South American erecting plants. According t British practice, these barges are built somewhat after the man ner of an ocean-going ship; that is, only general drawings ar made, and all the detail work is laid out in the mold-loft, wher

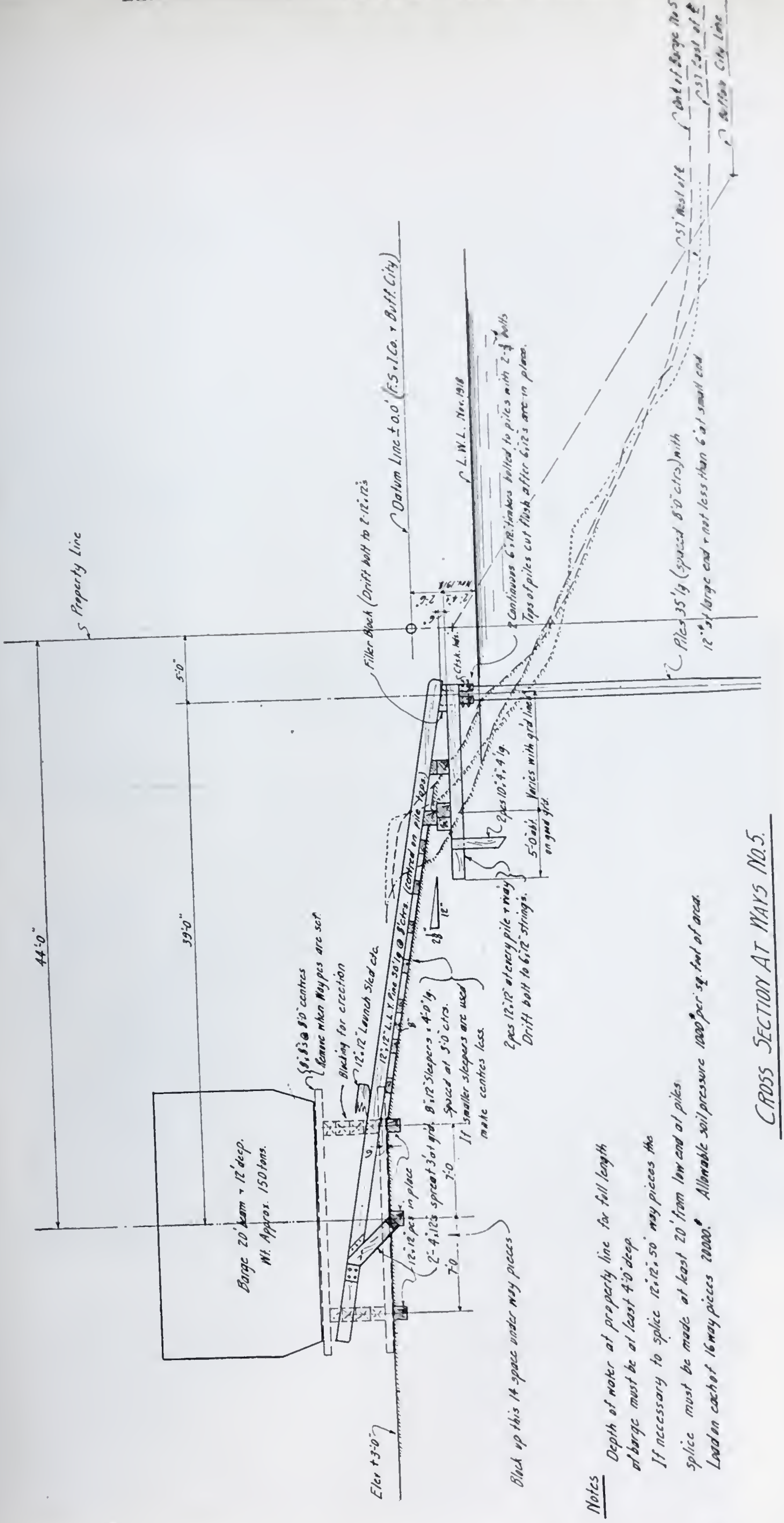


Fig. 20. Launchways for Barges at Works of Ferguson Steel & Iron Company, Buffalo.

all necessary molds are made. The steel is then fabricated and each barge is erected prior to being knocked down for shipment.

American practice, on the other hand, is to make complete drawings and to make all parts interchangeable as far as that is practicable. That there is no necessity for erecting the barges prior to shipment, is demonstrated by the fact that on the canal barges built by us the only correction work that had to be done in the field was the drilling of four holes to each barge. Considering the simplicity of construction of these barges, there does not appear to be any reason why barges cannot be fabricated for export shipment as easily and with as great certainty of satisfactory results as any other kind of steel work.

Fig. 21. Erie Canal Barge, Showing Model for Half of One End from Which Plate Templets Were Lifted.

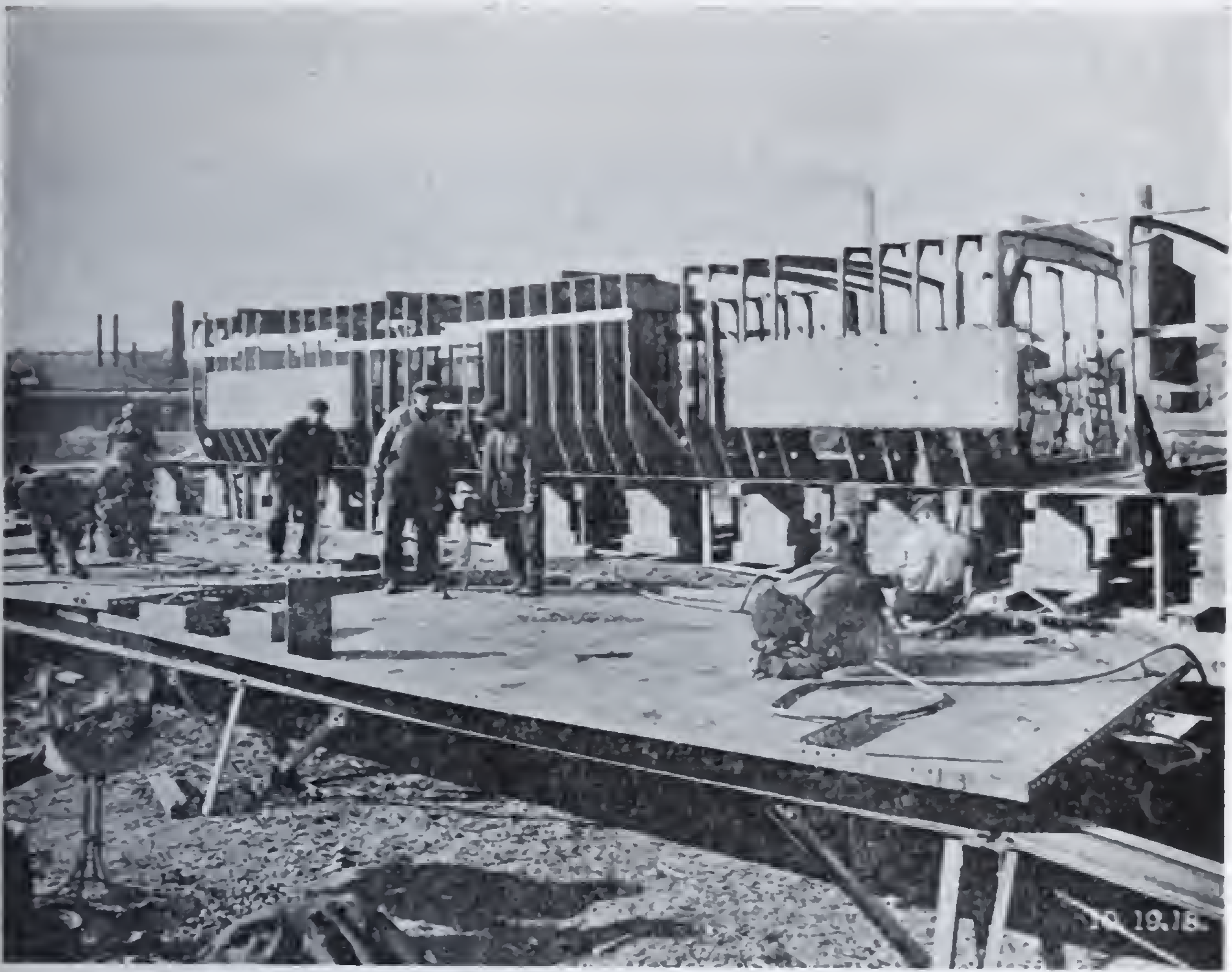


Fig. 22. Erie Canal Barge on Ways During Erection, Showing Bottom Plates, Frames, and Some Side Plates in Position.

Fig. 23. Erie Canal Barge Completely Assembled and Ready for Launching.

Fig. 24. Erie Canal Barge During Launching.

DISCUSSION

Mr. George H. Danforth:* I might say that this paper to-night is the result of pretty nearly nine months work on my part. It was the middle of last September when I first heard what the Ferguson Steel & Iron Company was doing in the way of barges, and it is through the courtesy of that company that Mr. Leach is here to-night. They have been doing some very remarkable work up there and I am very glad indeed that Mr. Leach was able to come down and give us a little account of what has been done. There is a great deal that Mr. Leach has not said which I hope will be brought out in the discussion.

Mr. V. B. Edwards:† I would like to ask a few questions in regard to these barges, not only as to fabrication, but also as to the work in the yard.

The speaker stated in the paper that it had not been necessary to countersink the rivets in the bulkheads and that the bulkheads had been assembled in one piece in the shop. I wonder if the frames were assembled in one piece at the shop, or shipped as loose pieces to the yard. In connection with the angle-irons or the fender angles that hold the fender timbers on the side of the barge, I would ask whether those angles were countersunk on the outside.

There are several other questions I would like to ask and I may as well ask them all at once. Another point is the fabrication of the bow of the barges. The barge frame angles are flared in the rake ends of the boat; each frame angle has a different, but uniform, flare. What was the method of doing the shop work on those flared angles?

In reference to the yard itself and the launching of the barges, I would ask what the reason was for making the slope of the ways as steep as it is, and whether the usual Great Lakes

*Structural Engineer, Jones & Laughlin Steel Co., Pittsburgh.

†Plant Engineer, Dravo Contracting Co., Pittsburgh.

method of releasing the boats was carried out. I would also like to have an idea of the approximate time it took to erect one or several barges.

MR. THOMAS LEACH: The frames were all assembled complete in the shop; also the ones we fabricated which were assembled in New York, were all assembled and riveted up together complete in the shop. We found that similar barges have been built by others, with button-head rivets instead of countersunk rivets, and they have been found absolutely water-tight. We did not do it, because we had some shipbuilding experience in our organization which advised us against using button-head rivets, as they were afraid we could not get them tight; but I do not think we would use countersunk rivets again, because we can drive button heads much more cheaply.

The fender angles were countersunk on the outside. They were also calked. I understand some of the builders of these barges for the Railroad Administration did not countersink these rivets. I do not think it is necessary, and we would not do it on our own specifications.

To minimize the grading, the slope of the launchways was made to suit the slope of the ground, therefore each way has a different slope. This slope varies from 2 to 3¼ inches per foot on different ways.

I might also state that we tried an experiment in countersunk punching. This work cannot be done on a multiple punch because these punches are not made heavy enough for the work of countersinking. If the punching runs about 12 cents a hundred, the countersinking will run about 15, and the work can all be done in one operation. There is no reason why a multiple punch cannot be made strong enough to countersink the holes at the same time, and this will effect a considerable saving in the fabrication of a barge. We have proved that it can be done in single punch work.

I think our assembling and our fabrication have also proved that barges can be fabricated and exported, knocked-down, with-

out being previously assembled. Our only field error was four holes to be drilled on each barge.

MR. V. B. EDWARDS: The Dravo Contracting Company, with which I am connected, also had a contract for 12 of these barges, and 11 of these are now in the water. We have launched one barge a week since the first of the year, and the last one will be launched during the present week. My questions in connection with the flared angles were for the purpose of comparing respective shop methods.

MR. THOMAS LEACH: They were flared under the punch.

MR. V. B. EDWARDS: I believe we flared them in a bulldozer. We had a die which was altered to suit the flare for each angle, and the 12 barges were put through in one operation. As to the matter of the steel, we obtained all of our steel some time ago. As a matter of fact we used some steel from our own stock, but not much.

MR. THOMAS LEACH: We completed ours from our own warehouse stock. It has not all been received yet.

MR. V. B. EDWARDS: In launching, have you taken any observations to give you a definite idea as to how much one of your boats lists?

MR THOMAS LEACH: No, we have not taken any particular observation beyond the ordinary observation with the eye. We found that one of our barges went down to within about 18 inches of the deck.

MR. V. B. EDWARDS: In launching barges from the dock, the launchways are between five and six feet above the water level and the barges drop about 7½ to 8½ feet, total drop. From the pictures, I imagine the amount of list is about the same as for your boats.

Mr. Thomas Leach: I saw the launching some weeks ago of a 3500-ton freighter. While it is generally conceded that you cannot drop a boat more than six feet without damaging it, that 3500-ton freighter was dropped 14 feet 7 inches and not a bit of damage done to it. In the same yard they drop them anywhere from 11 feet to 14 feet 7 inches, and they never had any damage done to a boat. They side launch into a slip about twice the width of the boat. That is at the Buffalo dry-dock.

Mr. V. B. Edwards: I might add that we launched a practically completed towboat on Saturday, with stern-wheel, engines, boilers, and piping, and even the upper cabin, in place. We dropped the boat only a couple of feet. There was absolutely no damage; the list was only a maximum of nine degrees, and the heaviest end of the boat went 18 inches lower than its normal draft after launching. Observations were taken to determine this very accurately.

Mr. Thomas Leach: I might say that our arrangements for the launching of tugs and barges are figured so that, theoretically, the barges would leave the ways at about 15 feet a second, and, as nearly as we could observe, that is about the speed at which they actually left. The tugs should leave the ways at about 12 feet a second, and our observations showed about 11 feet.

Mr. V. B. Edwards: Our runway is a little longer than that indicated in your illustration and a barge, in leaving goes about 20 feet a second.

Mr. Thomas Leach: Our tugs had 45 feet of travel before they hit the water and the slope was 1⅜ inches to the foot.

Mr. V. B. Edwards: Ours was 1¾ inches to the foot.

Mr. E. W. Pittman:* Were the calking edges of these plates beveled?

*Chief Engineer and Manager, John Eichleay, Jr. Co., Pittsburgh.

Mr. Thomas Leach: No, all the plates were straight sheared, not bevel sheared.

Mr. Samuel E. Duff:* What was the distance between the punches and the dies in that countersunk punching?

Mr. Thomas Leach: One sixty-fourth of an inch on the diameter. The burrs resulting from punching were not taken off but did not prove objectionable.

Mr. Samuel E. Duff: You put in a good many bolts, then?

Mr. Thomas Leach: One in every fourth hole.

Mr. E. W. Pittman: Did you have many leaks in the barges after launching?

Mr. Thomas Leach: None whatever; though we got an 85-mile wind from the lake when we had 12 boats in the water. Some of the boats drifted on the shore, but there was no damage done. The storm came up at one o'clock in the morning when we were not expecting it and the water rose 3½ feet in half an hour.

Mr. E. R. Spencer:† Did you make any calculation of ram pressure when you countersunk those holes?

Mr. Thomas Leach: No.

Mr. E. R. Spencer: How many holes a day did you get?

Mr. Thomas Leach: A maximum of 6000.

Mr. E. R. Spencer: I understand some shipbuilding shops claim to have done a good deal better than that.

*Consulting Engineer, Empire Building, Pittsburgh.

†Thomas Spacing Machine Co., Pittsburgh.

MR. J. H. MINTON:* I would like to ask Mr. Leach what has been done in the way of terminals for handling these barges, and if, in their design, any consideration has been given to handling them at terminals; although I realize that this terminal proposition is somewhat beyond the scope of this paper.

MR. THOMAS LEACH: There is one terminal now under construction at Buffalo. It was designed during the war, and was intended to be a wooden building, but two weeks ago the design was changed to structural steel. Other terminals have been built, one of which is at Troy, N. Y., but I think only a very small part of the terminal program has been carried out.

There is some discussion now in regard to building grain elevators in New York for handling grain brought through the State Barge Canal. Until this is done, it will be impossible to utilize the full benefit of the canal. I have some figures on the transportation of grain. I did not bring them along, but they would make very interesting reading. I would recommend reading the 1918 report of the Superintendent of Canals which may be had from the State Department in Albany.

MR. E. R. SPENCER: Regarding the difficulty of which you spoke with reference to the sagging of the plates in the lighter gages, would this trouble have been experienced if the distance between the sets of rollers carrying the plate had been less?

MR. THOMAS LEACH: I don't think so. The entire plate was lifted up.

MR. E. R. SPENCER: Then the stripper was not set low enough. On the other hand, if the plate presses very much against the stripper, due to sagging, the driving rollers can drag the plate along only with difficulty, and the operator cannot help matters much by adjusting the height of these driving rollers. It should be possible for one operator to handle plates without help while they are on the table, if the stripper is really to fulfill its function as a labor-saving device.

*Assistant Engineer, Pennsylvania Lines, Pittsburgh.

Mr. Thomas Leach: The stripper may have been set a little too far away from the plate. These plates were so thin that we had difficulty in keeping them absolutely flat.

Mr. H. K. Higgins:* You may perhaps be interested in some barge work that was done on the Panama Canal construction. That was quite a while ago but it applies to this question of barge design.

We bought and used quite a number of barges on that job. Some were shipped complete and some knocked down or fabricated ready for assembly. Those shipped complete were towed from North Atlantic ports past the stormy Delaware capes without serious trouble; some six barges being roped together into a tow, each with another barge upside down on the deck. The season was fairly stormy, although not excessively so.

It would therefore seem that we have not entirely exhausted the possibilities of shipping barges complete to South American or other ports.

This seems especially true in view of the extensive coal traffic hat moves all the year in barges from New Jersey and Virginia ports to north of Cape Cod. New England manufacturers are argely dependent upon this coal.

The knocked-down barges shipped to Panama were put together on the Isthmus at considerable expense. They would have ost less to build complete at the fabricating yard. Of course, he conservative practice was in line with that generally followed; f justification is necessary.

Some of the designs shown this evening—the later ones—ppear to be a distinct advance over the old-fashioned idea of arges. It would seem that there is a chance to improve on former leas, particularly in barges for inland canals, in the direction of utting out odd things we used to think needful—dead rise, shear, amber, etc.—using straight lines, getting good easy construcon, reducing construction cost, and, thereby overhead on transortation.

*Assistant Engineer, Aluminum Co. of America, Pittsburgh; formerly ssistant Engineer, Panama Canal.

We have yet to realize on our investment in the New York Barge Canal. A large part of our success will lie in the provision of boats or barges of low cost, which will operate with small crews and small overhead charges.

This suggested principle of straight lines in design was also approached in the design of some of the Panama dredges. The pipe-line dredges were designed with a minimum (for those days) of curved and forged work.

Some of the designs shown this evening seem heavier than necessary. This is, of course, only a detail—one easily modified, if desired. The main thing is to standardize design so that any structural or tank shop can turn out barges.

The illustrations will show that launching is not as important a feature as some of us had supposed.

FEED-WATER TREATING AND PURIFYING PLANT FOR THE REPUBLIC IRON & STEEL COMPANY, YOUNGSTOWN, OHIO

By S. H. McKee*

As preliminary to describing the boiler feed-water purifying system installed by the Republic Iron & Steel Company to serve its various plants at Youngstown, O., I wish to state that it is not my purpose or intention to discuss the relative merits of the equipment entering into the construction of this plant, as compared with equipment of a like nature, but to give you a general outline of the conditions and problems that confronted us, and our solution of our particular difficulties, with a general description of the equipment and its operation.

The question of good feed-water for our boilers had been under consideration for some time, but it was not until the year 1916 that it was definitely decided to install a treating system.

As most of you are probably aware, the Republic Iron & Steel Company has five plants located along the Mahoning River, beginning with the Bessemer and Brown-Bonnell plant, which is in the center of the city of Youngstown and ending with the by-product coke works, located about three miles down the river, with the tube works, open-hearth works and Haselton blast-furnaces lying in between.

It was our intention to install a water softening and purification plant of sufficient capacity to satisfy the boiler feed requirements at these five plants, not only for the conditions that existed at that time, but for any future extensions that might be made.

*Chief Engineer, Republic Iron & Steel Co., Youngstown, O.

The average boiler horse-power developed at our plants was:

Bessemer and Brown-Bonnell plant..	24 000	boiler	horse-power
Tube works	500	"	"
Open-hearth works................	4 100	"	"
Haselton furnaces................	20 000	"	"
By-product coke works............	1 900	"	"
Total.....................	50 500	"	"

The peak loads ran to 78 000 boiler horse-power, but as it was improbable that the peaks would occur in all the plants at the same time it was thought advisable not to pay too much attention to this figure.

It was decided to use the Mahoning River water as the source of raw water supply. We carefully considered, however, the use of the waste condensing water from our barometric condensers at the open-hearth plant on account of the higher temperature of this water, but, due to the distance of the available location of the water-softening plant from the condensers, the matter was dropped.

It was decided to locate the treating plant at the open-hearth works, which is just across the Mahoning River from Haselton furnaces and is centrally located with respect to the outlying plants. This location also had the advantage of being in the neighborhood of the unoccupied property of the Republic Iron & Steel Company and any future extensions would be made on this property. Furthermore, the greatest boiler generating capacity was concentrated in this locality. As an added incentive, there was a 16-inch water line running between the open-hearth plant and the Bessemer and Brown-Bonnell plants, that could be used to advantage.

As previously stated, the five plants which it was proposed to supply with treated water, had a combined average boiler horse-power generation of 50 500, requiring a treated water supply of 200 000 gallons per hour; but, in considering the capacity of the purifying system, it was necessary not only to provide for the present, but, as emphasized before, to provide for any developments of the future. A careful study was made of this problem

and it was found that it would be necessary for us to provide for an additional generating capacity of 35 000 boiler horse-power. This meant that to meet average future conditions, we must ultimately provide a plant to take care of 85 500 boiler horse-power, or to supply 335 000 gallons of treated water per hour.

The plant, as installed, has a treating capacity of 300 000 gallons per hour and it is so laid out that a 25 per cent. extension can be made, giving us an ultimate treating capacity of 375 000 gallons per hour, which will safely meet any future demands that might be made on this plant. You will observe that the capacity of the plant as installed is very liberal, using our present requirements as a basis, but we felt that this was justified, particularly on account of its importance in that in our plans we are dependent entirely upon this source of supply for a good and sufficient feed water for our boilers, although, as a safety measure, our feed water heaters are connected to our service lines at our various works, this supply of raw water coming into action automatically if any serious stoppage in the supply of treated water should occur.

Our intention was to locate the water-softening plant directly on the river bank and make the raw water intake an integral part of the plant proper, but, due to local conditions that made it essential that we preserve two railroad tracks on the river bank, it was necessary to locate the softening plant about 50 feet from the river.

A two-compartment intake was built on the river bank, each compartment being provided with stationary and motor-driven traveling screens, and with sluice-gate valves operated from yard level to enable each compartment of the intake to be cut off from the river connection. Each compartment is of ample capacity to take care of the maximum ultimate requirement of the water-softening plant. Concrete tunnels were constructed, connecting each section of the intake with a separate pump-well under the pump-room in the softening plant. These tunnels are of sufficient cross-section to allow for proper cleaning, and a manhole is provided for ready access to the tunnels so that any accumulations may be easily removed.

The volume of flow in the Mahoning River varies through a wide range. By what is known as the Milton reservoir, located at the source of the Mahoning River, water is held in storage for use during the dry summer months when the minimum flow is supposed to be kept at 80 000 000 gallons per day, but even with this provision the minimum flow varies greatly. In dry weather the total volume of flow, in its passage through the city of Youngstown, is used a number of times, by the large industrial plants—the Republic Iron & Steel Company, alone, pumping the minimum flow twice over.

To assure sufficient water at all times, it is necessary to hold the water in storage by means of dams along the river. The great variation in the volume of flow causes great variations in the amount of suspended matter and hardening substances. Analyses of the water over a series of years show 7.05 grains per gallon of hardening substances as a minimum, and 25.44 grains per gallon as a maximum. The carbonate hardness ranges from 0.75 grains per gallon to 6.73 grains per gallon and the permanent hardness—which includes the sulphates, chlorids, and nitrates of lime, magnesia, and iron—ranges from 3.4 grains per gallon to 23.56 grains per gallon. The suspended matter varies between 0.25 grains minimum and 8.75 grains maximum.

The sewage from the city and the wastes from all manufacturing plants above us, and extending as far as Warren, O., are discharged into the river and the impurities thus introduced, in addition to the suspended matter and the hardened water in its normal condition, make it an undesirable feed-water supply, without purification where high rates of evaporation are to be maintained.

To take care of our conditions, we decided to install a cold process system of the intermittent type, because of its demonstrated efficiency in treating Mahoning River water, as it was found that with this system, in which the treatment of the water is carried on in fixed volumes, the result was a water that is uniformly softened and at all times clear, regardless of the variations in the condition of the river.

In this system, treatment with each reagent is made separately and the results of each can be accurately checked; intro-

duction of the reagents is not dependent upon proportioning devices, but is made directly with definite weights, into a fixed volume of water; there are no complicated mechanisms connected with making the treatment or in control of the flow; the reagents are completely diffused through the water by mechanical means; the reactions and settling are completed while the water is static; the reaction and settling tanks hold sufficient water to obtain full treatment periods; the treatment of the water is independent of varying rates of use, there being no direct connection between the introduction of reagents into the water and the rate of flow; complete filter equipment supplements the softening process, insuring water free from precipitates or suspended matter that may have been in the raw water.

The ground space occupied by this installation is 260 by 79 feet, the reaction and settling tanks occupying a space 166 by 79 feet, and the operating and filter building occupying the remainder.

The entire foundation is set 7½ feet above yard level to guard against flood conditions, and the foundations for both building and tanks are thoroughly waterproofed to prevent leakage. There are eight reaction and settling tanks built of steel—37 feet in diameter and 35 feet high, arranged in two parallel rows, with tanks 40 feet from center to center, and four tanks per row. Stairways and platforms are provided to allow ready access to the top of the tanks, with tunnels and passageways in foundations underneath the tanks to house the filling and delivery piping and operating mechanisms, all being easily accessible for inspection and repair purposes.

As previously stated, pump-wells are provided under the pump-room connecting with the tunnels and intake. This pump-room is located in the operating and filter house in the end of the building towards the reaction and settling tanks. This building is 94 feet long, 62 feet wide and two stories high above the foundation level. Below ground level, at a distance of 12 feet 6 inches, is located the floor of the pump-room which is 58 by 36 feet. In the end of the building away from the reaction and settling tanks, located below ground level, is the purified water basin or clear well, which is 58 feet by 52 feet 6 inches, and 14 feet deep, holding 295 000 gallons of water.

Over the clear well are the filter units, eight in number. These are 20 feet by 12 feet 6 inches, and 9 feet 3 inches deep, arranged in two rows of four each. Between these is a pipe gallery 12 feet wide, with a head room of 8 feet 10 inches, the floor of this gallery being at the same elevation as the bottom of the filters. The pipe gallery is floored over at the same elevation as the top of the filters. At the end of the filters and clear well this floor is extended across the basement, which contains the pumps. A portion of the floor immediately over the pumps is cut out to provide light and ventilation. This same floor level, or first floor, is the main operating floor of the purifying apparatus. On it are located the panels on which are mounted the control devices of the hydraulic valves and the alarm bells and switches for motors. There are also on this floor the recording gages, the sample line faucets and basins, the apparatus for testing the samples of water, and the valve-stem extension stands for the operation of the filter valves. On this same floor level, or first floor, there is a separate dust-proof room, 10 by 42 feet, and 14 feet high, in which are installed six reagent-mixing tanks. In this room the charges of reagents for treating the water are made up, and from here delivered to the reaction and settling tanks.

The second floor of the pump and filter house is used for the storage of chemicals and for weighing out the charges required for treatment. This floor is reached by an elevator, having an outside entrance to an unloading platform 3 feet 6 inches above ground level and served by a standard-gage railroad track.

Stairways are provided connecting all floors of the building and the building proper is constructed with a steel frame, brick curtain-walls and steel sash with reinforced concrete floors and with a concrete slab roof covered with built-up roofing, this construction resulting in a very attractive and well lighted building.

Inasmuch as the capacity of the treating apparatus was based on the operation of the settling tanks in pairs—each pair having a capacity to provide water at the rate of 300 000 gallons per hour for 1 2/3 hours on the basis that we provide water for filling a pair of tanks in one hour, or at the rate of 500 000 gallons per hour—we supplied, to perform this service, two pumping

units, each capable of delivering 10 000 gallons of water per minute against a 70-foot head. Each unit consists of a horizontal, single-stage, double-suction, centrifugal pump, driven through reduction gears by a condensing steam-turbine, and each unit is of ample size to meet the ultimate demands of future requirements.

It will be noted that we have provided a dual installation of intake, tunnels, wells, etc., to supply these pumps with the necessary water, and each system can be cut off at will and cleaned, as the remaining system is of ample size to take care of all requirements.

The raw water from the supply pumps is delivered to the reaction and settling tanks through a 20-inch main from which 14-inch connections are made to each of the tanks. These pipe connections are through the bottoms of the tanks. Each tank connection is provided with a branch, which is connected up with a sewer line. The valves in both the filling and the sewer connections are hydraulically operated, with an emergency shut-off valve between the hydraulic valve in the filling line and the water-main. Any tank or pair of tanks can be isolated, if necessary. Each tank is equipped with a mechanical stirring device, operated by an individual direct-connected electric motor. The stirring device shafting passes up through the bottom of the tank through a stuffing-box. Each tank is provided with two float-operated electric alarms with bells located in the operating house. The first alarm is set to operate four feet from the top of the tank and the second alarm eight inches from the top of the tank. The first alarm rings to notify the operator to be prepared to close the valve. This is necessary on account of the rapid rate at which the reaction tanks are filled. By having the alarm bell ring when the water level is within four feet of the top, sufficient time intervenes before the tank is full, to enable the operator to get in position to close the valve. The ringing of the second alarm calls for the instant closing of the valve and the interval of time required for the operation of the hydraulic valve completes the filling of the tank to the proper level. Each tank is also equipped with a recording altitude gage which registers the time required for filling a tank; the time the tank is settling and the time in which it is emptied; the time consumed in washing filters, and

the amount of water so used; the charts of these gages giving an accurate record of the treatment cycle of each tank.

The water, after being treated and settled, is drawn from the tanks through a floating outlet pipe 14 inches in diameter, which takes the water from the top and follows the descending level until a stop, carried on the pipe, rests on the bottom of the tank, holding the pipe at a fixed elevation to insure a uniform emptying depth and to avoid running sludge to the filters. These floating outlet pipes are connected to the bottoms of the tanks through a special form of flanged elbow, which permits the pipe to move in a vertical plane, but prevents movement in a horizontal plane. These floating outlet pipes are connected to an 18-inch main. Each connection is provided with a hydraulically operated valve and, in addition, there is an emergency shut-off valve between the main and the hydraulically operated valves. The main is carried to the filters, where it is divided into two lines, each supplying four filter units.

The controls, reagent mixing tanks, etc., are located in the operating and filter house on the operating floor.

The controls for each reaction tank are mounted on individual marble panels and these different panels are assembled in two rows of four panels each, similar to a switchboard. Each panel has a recording altitude gage; three control handles connected to four-way cocks for inlet, sewer, and outlet valves to and from the reaction tanks; a push-button motor starter for the stirring devices; and a switch for the high-water alarm. At the end of each row of operating panels there is a panel fitted with a two-pen recording thermometer indicating the temperature of the incoming and of the outgoing water; also an indicating pressure-gage for the hydraulic system, a discharge-line recorder, and four sample bibs mounted over a sink. These sample bibs are connected with one-inch lines to the different reaction tanks for drawing samples of the treated water for testing.

Pressure for operating all hydraulic valves is obtained from a pair of duplex steam-pumps located in the pump-room of the building—one of these pumps being a spare. The water is drawn from a sump that is lubricated by soap in solution, then forced by the pumps through a pneumatic water-supply tank into a main

from which connections are made to four-way cocks controlling the different hydraulically operated valves. From each four-way cock, two ¾-inch pipe-lines run to the cylinders of the hydraulically operated valves. These ¾-inch lines are alternately used to transmit the pressure to the cylinder and to return the waste water through the four-way cock to the waste main discharging into the sump, so that the water is used over and over through the valve cylinders. The pressure used is 70 pounds to the square inch.

Six reagent-mixing tanks are provided in two rows of three tanks each, so that three different reagents can be prepared simultaneously for making treatment in two reaction tanks at the same time. These reagent-mixing tanks are fitted with motor-driven stirring devices with silent-chain drive and friction clutches. The tanks are provided with separate steam and water connections and outlet connections to the reagent pump suction. The charges of reagents are weighed out on the storage floor and then dumped into hoppers which are hung through the floor, the hoppers having outlet gates at the lower end through which the chemicals are allowed to fall into the reagent-mixing tanks.

In the pump-room under the reagent-mixing tank room there are three centrifugal pumps for delivering reagent solutions to the reaction tanks. These three pumps are located and connected in such a way that the third pump is a spare for use with either row of reagent tanks. The discharge piping from the reagent pumps is arranged so that each pump supplies four reaction tanks. The suction connections to the pumps are arranged so that the reagents from any one of the three reagent-mixing tanks can be pumped to any of the four reaction tanks. The connections from the reagent-mixing tanks to the reagent pumps are arranged to give a flooded suction and are also arranged so as to by-pass either set of three tanks to the spare reagent pump. All operating valves in both the suction and the discharge lines, for regular operation, are operated from the reagent-mixing, tank-floor level. The reagent solution discharge lines pass from the basement through the end wall of the operating house and are carried under the stairway and platform to the top of the reaction and settling tanks.

The delivery of water from the reaction and settling tanks to each filter is controlled by a balanced double-disk valve, operated by a float in the filter. The outlet from the filters is discharged into the purified water basin immediately under the filters and under the pipe gallery. This basin is equipped with an indicator to show the water-level and also equipped with a recording altitude gage to register the water-level at any period of the day.

In the discharge pipe from the filter, there is a balanced double-disk valve controlled by a float in the purified water basin, so that when the level of the water in this basin reaches the maximum height the valve on the filter outlet closes. This, in turn, raises the level of the water of the filter-bed, so that the float-controlled valve on the inlet to the filter is closed, and the water held in the reaction and settling tanks. An auxiliary float is connected with the balanced valve on the outlet of the filter, so that in case the water-level within the filter drops to a predetermined level the outlet valve is closed. This serves to prevent the filter from draining; and keeps the water-level in the filter at sufficient depth over the filter-bed to prevent breaking up of the quartz bed when the supply of water is turned into the filter.

Each filter unit is equipped with an inlet valve, a sewer valve, a wash valve, and an outlet valve, in addition to the float-controlled balanced valves on the inlet and outlet. The arrangement of the pipe connections to the filter units is such that any or all of the filters can be operated with any or all of the reaction and settling tanks discharging water through the floating outlet pipes. The filters are equipped with a special form of brass strainer screwed into a manifold, with the strainers uniformly distributed over the area of the filters—approximately 7½ inches from center to center. The filters are also equipped with an individual air-washing system consisting of ¾-inch brass laterals (iron pipe standard) drilled for a uniform distribution of air. This air piping is placed immediately above the strainer piping in the filter bed.

Air is supplied from a direct-connected, motor-driven, positive blower located in the pump-room. The discharge line from the blower is equipped with a pressure relief valve to control the air pressure within the line so that it does not exceed two pounds

to the square inch. The regulation of the air pressure insures uniform washing and avoids wasting quartz.

The filter-bed consists of graded gravel, having a depth of 10 inches, and two layers of crushed quartz, the total depth of the filter bed being 21 inches.

The filters are equipped with wash troughs suspended from the side walls, the top edges of the troughs being 14 inches above the quartz bed. The troughs are placed so as to get an even overflow of water into all sections of the filter. During the regular operation of the filters, the wash trough is submerged. When washing the filter, the level of the water in the filter is at the top edge of the trough, and the volume of water introduced is controlled so as to get a weir effect over the edge of the trough. Water for washing is by-passed from the supply to the filters, and introduced through the strainer manifold. The strainers are of special design and, when washing, they automatically adjust the openings so that the combined discharge of the strainers is slightly less than the volume carried by the wash pipe. This design results in the uniform distribution of the water throughout the filter-bed with a minimum waste of water in washing. The wash water required is between 1 and 1½ per cent. of the water filtered. The separate introduction of water and air enables the operator to do the washing quickly and efficiently.

The treatment of the water is carried out as follows: The charges of lime, ferrous sulphate, and soda-ash are weighed out and put into the reagent-mixing tanks. The lime is slacked so as to be ready for introduction into the reaction and settling tank when the filling of the tank begins. As soon as the filling of a reaction and settling tank begins, the charge of lime is pumped into the tank and the stirring device in it is started. The stirring device is kept in operation during the entire period of filling the tank and no other reagents are introduced until the tank is full, the filling time being one hour. When the tank is full, the charge of ferrous sulphate is introduced and 10 minutes afterwards the sample of water is taken for testing the correctness of the treatment with lime and ferrous sulphate. Following the introduction and mixing of the ferrous sulphate, the charge of soda-ash is introduced and the stirring continued for 15 minutes thereafter.

The stirring device is then stopped and the water allowed to stand quiescent for reaction and settling for 2¾ hours. Thirty minutes after the stirring is stopped a sample of the fully treated water is drawn for testing. At the end of the settling period, the water is delivered to the filters as required.

The floating outlet pipe is flushed into an empty tank before turning the water into the filters. This washes out the sludge that has accumulated in it and prevents fouling the filters. The floating outlet pipe draws off the clearest water from the top of the settling tank and follows the lowering of the water-level.

The precipitates settle out of the water ahead of the pipe, so that there is only a minimum of sludge carried to the filters. The stop on the pipe prevents it from reaching a position where settled sludge will be carried to the filters. The softened and settled water, after passing through the filters, is delivered into the clear well. The precipitate resulting from the reaction accumulates in the settling tank. When this precipitate reaches a depth to cover one-half the height of the paddles, it is removed by starting the stirring device and mixing it with the water remaining in the tank when the floating outlet pipe has reached its lowest position; then opening the sewer valve and flushing into the sewer.

A correction factor for the charges of reagents is used for the charges first introduced after the sludge has been washed from the tanks.

The rate of flow of the softened water from the settling tanks to the filter is controlled by the position of the water-level in the clear well and, with the clear well full, the inlet valves on the filter automatically operate to hold back the water in the settling tank. The clear well acts as a balancing tank between the demand for water and the supply coming from the reaction and settling tanks. When the demand for the water exceeds the capacity of the equipment, extra water is supplied from the clear well. During periods of small demand the clear well supply accumulates.

The function of the filter is to remove the crystalline precipitate that is too fine to settle and to guard against the possibility of dirty water from the settling tanks, from any cause, getting ino the boiler feed system. With the high efficiency obtained in

settling, the filters do not rapidly become fouled. It is necessary to wash a filter only about every three or four days.

The equipment is designed to operate two reaction and settling tanks simultaneously and, with the four pairs of tanks, the alternate filling and emptying of a pair maintains a constant supply of water.

The interval for settling, together with the volume of water held by the purified water basin, or clear well, gives sufficient time to treat properly all of the water used.

To deliver treated water from the clear well to the various plants two pumps were installed, each capable of pumping 5000 gallons of water per minute, against a 145-foot total head. Each unit consists of a horizontal, single-stage, double-suction, centrifugal pump driven through reduction gears by a condensing steam-turbine, and each unit has sufficient capacity to meet any future demands; although it was deemed advisable to provide room for the installation of an additional pumping unit.

In the delivery of treated water to the various plants we were confronted by a problem which I think will prove of particular interest. Under average conditions it required a total head of 137 feet to deliver the necessary quantity of water to the Bessemer and Brown-Bonnell plant through the 16-inch pipe that was in place, but under peak conditions at this plant it required a total head of 245 feet to supply the necessary quantity of water. The maximum total head required to deliver the necessary quantity of water at the other plants was 127 feet. A pumping unit capable of delivering the quantity of water required at peak conditions of a 245-foot head at the Bessemer and Brown-Bonnell plant would necessitate a two-stage centrifugal pump with a turbine of sufficient size to take care of this load. We carefully investigated our peak conditions over a considerable period of time and discovered that their maximum length of duration was 12 minutes. Our solution of this problem was to build a storage make-up tank of 20 000 gallons capacity, set adjacent to our feed-water heaters at the Bessemer and Brown-Bonnell plant, and placed at a sufficient elevation to deliver water to the feed-water heaters by gravity. It required a total head of 134 feet to fill this tank, but,

in order to be on the safe side, we purchased our pumps to work against a 145-foot head and were able to use single-stage, centrifugal pumps. This tank is under control of a motor-operated valve, set in the vertical supply line, and controlled by the pressure under the valve. Should this pressure drop, due to the occurrence of peak conditions, the motor automatically opens the valve and the necessary make-up water held in storage is supplied to the feed-water heaters. This valve remains open until such a time as the water requirements decrease, and the tank is filled when the valve is automatically closed by the building up of pressure in the supply line.

As has been previously noted, the supply and delivery pumps are steam-turbine driven and in connection with these units we installed a water-works type of condenser in the pump pit of the water softening building proper. The treated water is used for condensing purposes as there was a much larger quantity at all times than necessary for this purpose and it was a very simple matter to pass the water through the condenser on its way to being delivered to our various plants. A by-pass is provided for passing the treated water around the condenser should this become necessary. A master Venturi meter for check purposes is provided in the main delivery line just outside of the water softening building proper, and most of the feed-water lines at boiler houses at our various plants are provided with Venturi meters, and it is our intention to install meters at all of our boiler plants as soon as possible.

Analyses of the Mahoning River before softening and purification are shown in Table I with analyses of the water after being softened. In these softened water analyses, you will note the absence of the sulphates, chlorids, and nitrates of lime, iron, and magnesia; also, that the total of the residual lime as calcium carbonate and the residual magnesia as magnesium hydroxid, is less than 2.0 grains to the gallon. In addition to the reduction in incrusting solids, the water is free from suspended matter, the turbidity being zero.

Various features of the installation are shown in Fig. 1–7.

TABLE I

MAHONING RIVER WATER

	Grains per U. S. Gallon					
	Raw	Treated	Raw	Treated	Raw	Treated
Volatile and organic matter	1.15	.65	.95	.75	1.05	.65
Silica	.45	.45	.75	.75	.75	.45
Oxids of iron and aluminum	trace	trace	trace	trace	.05	trace
Calcium carbonate	2.43	.88	2.80	.60	3.20	.80
Calcium sulphate	11.32	....	5.03	....	3.94	....
Magnesium sulphate	4.86	....	3.84	....	2.88	....
Magnesium hydroxid		.48	....	.17	...	.23
Sodium carbonate		2.78	....	2.12	...	2.00
Sodium sulphate	.53	18.46	4.40	15.05	.85	8.95
Sodium chlorid	9.40	10.22	2.45	2.57	2.22	2.34
Sodium nitrate		....	trace	trace	.17	.17
Sodium hydroxid		.94	....	1.36	....	.64
Manganese carbonate	.08	....	....	....	....	....
TOTAL SOLIDS	30.22	34.86	20.22	23.37	15.11	16.23
Suspended matter	.65	trace	.45	filtered out	1.45	trace
Free carbonic acid	.25	none	none	none	.25	none
INCRUSTING SOLIDS	19.14	1.81	12.42	1.52	10.82	1.48
NON-INCRUSTING SOLIDS	9.93	32.40	6.85	21.10	3.24	14.10

With this equipment, we have found that it is possible to control the treatment of the water and to keep it within any desired limits.

There is a striking contrast in the appearance of the water before being softened and purified and the water as delivered into the clear well, and the system is giving us the anticipated results.

In closing, I wish to extend a cordial invitation to the members of this Society to visit our plant—which it is my understanding it is your intention to do—as I think from a personal inspection you will be able to learn more than I have been able to tell you this evening.

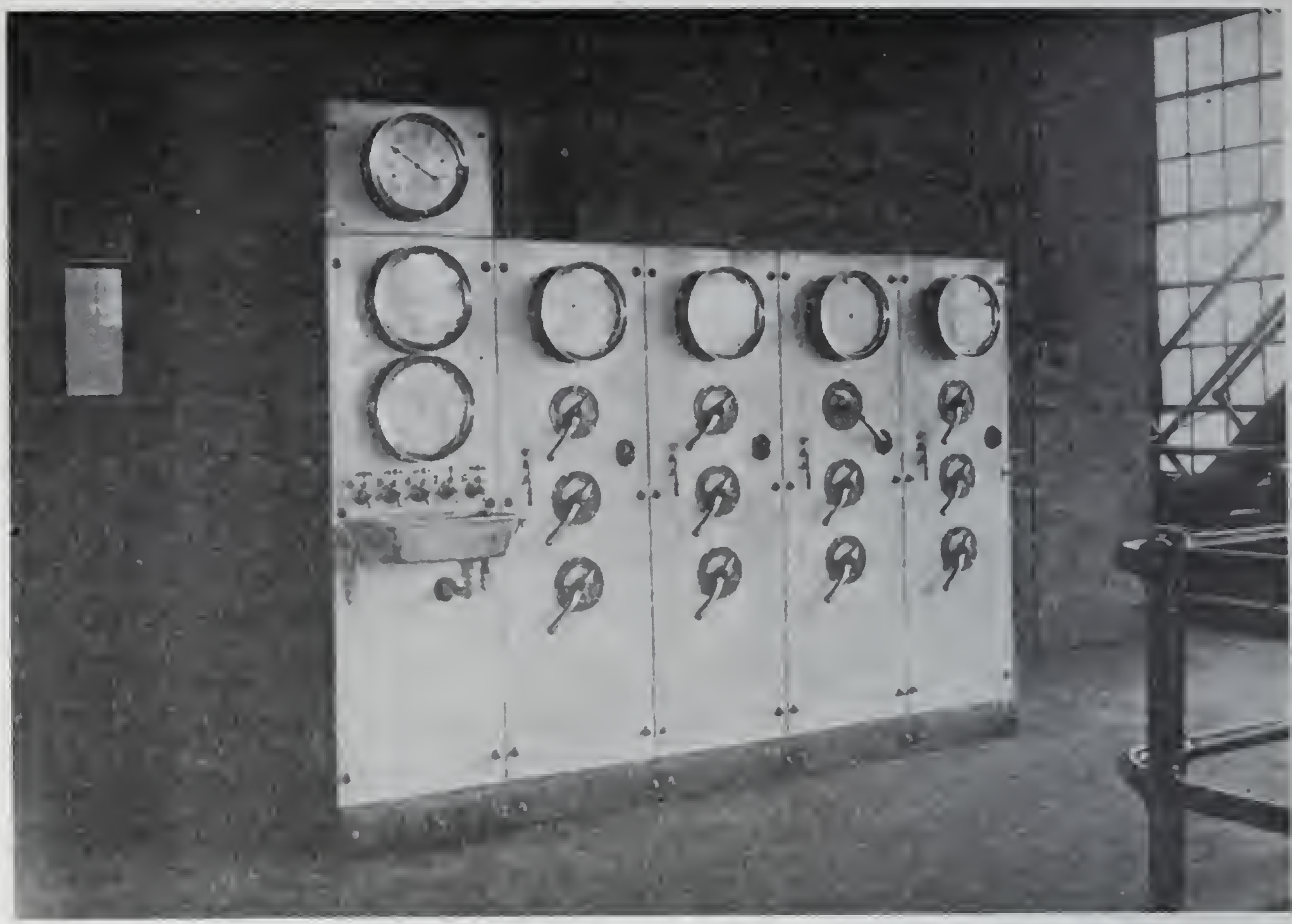


Fig. 1. Recording Gages, Sample Faucets, and Operating Board for Valves and Motors.

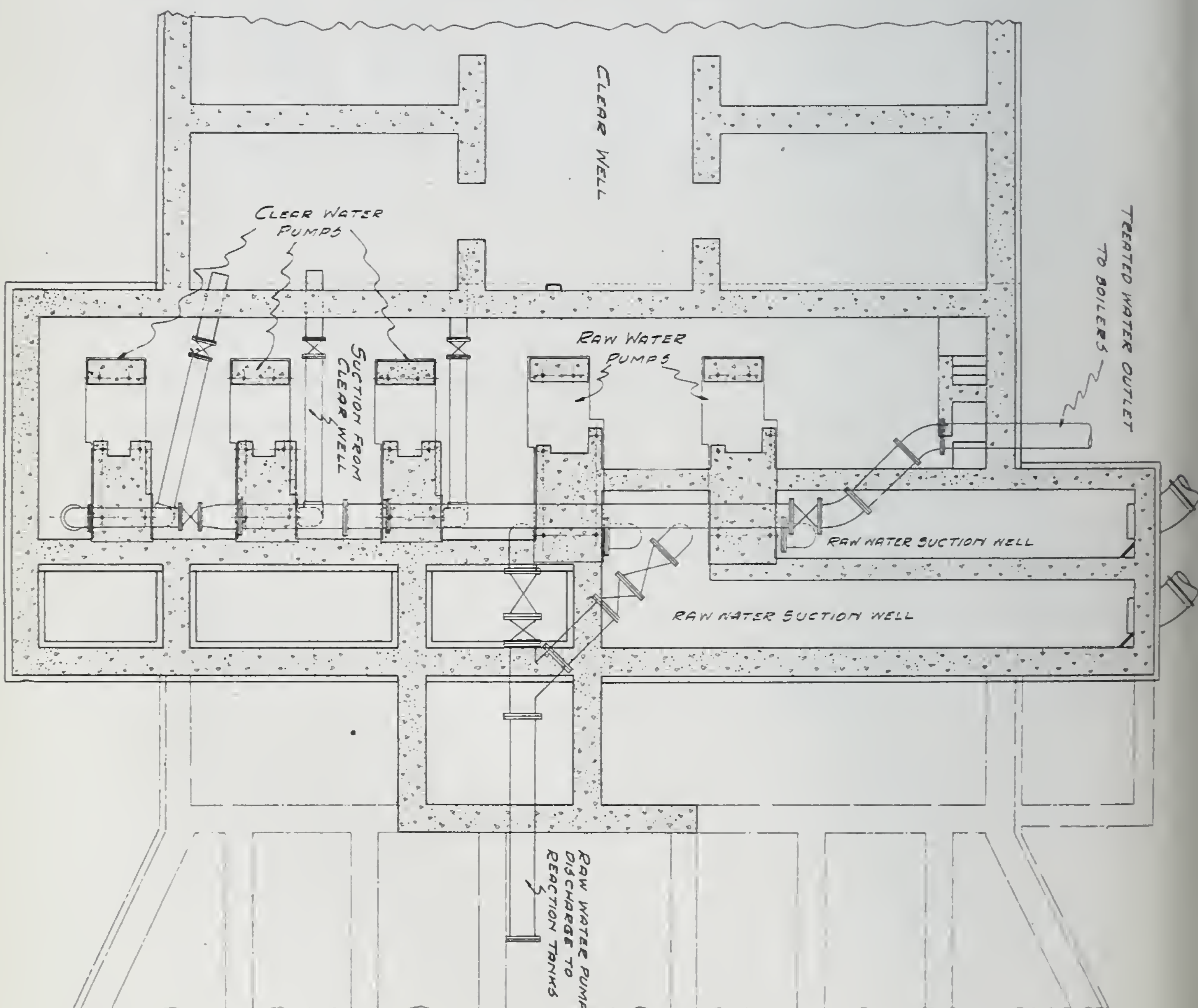


Fig. 2. Intake Tunnels and Pump Connections.

Fig. 3. Exterior of Installation.

Fig. 4. Interior of Filter and Operating House.

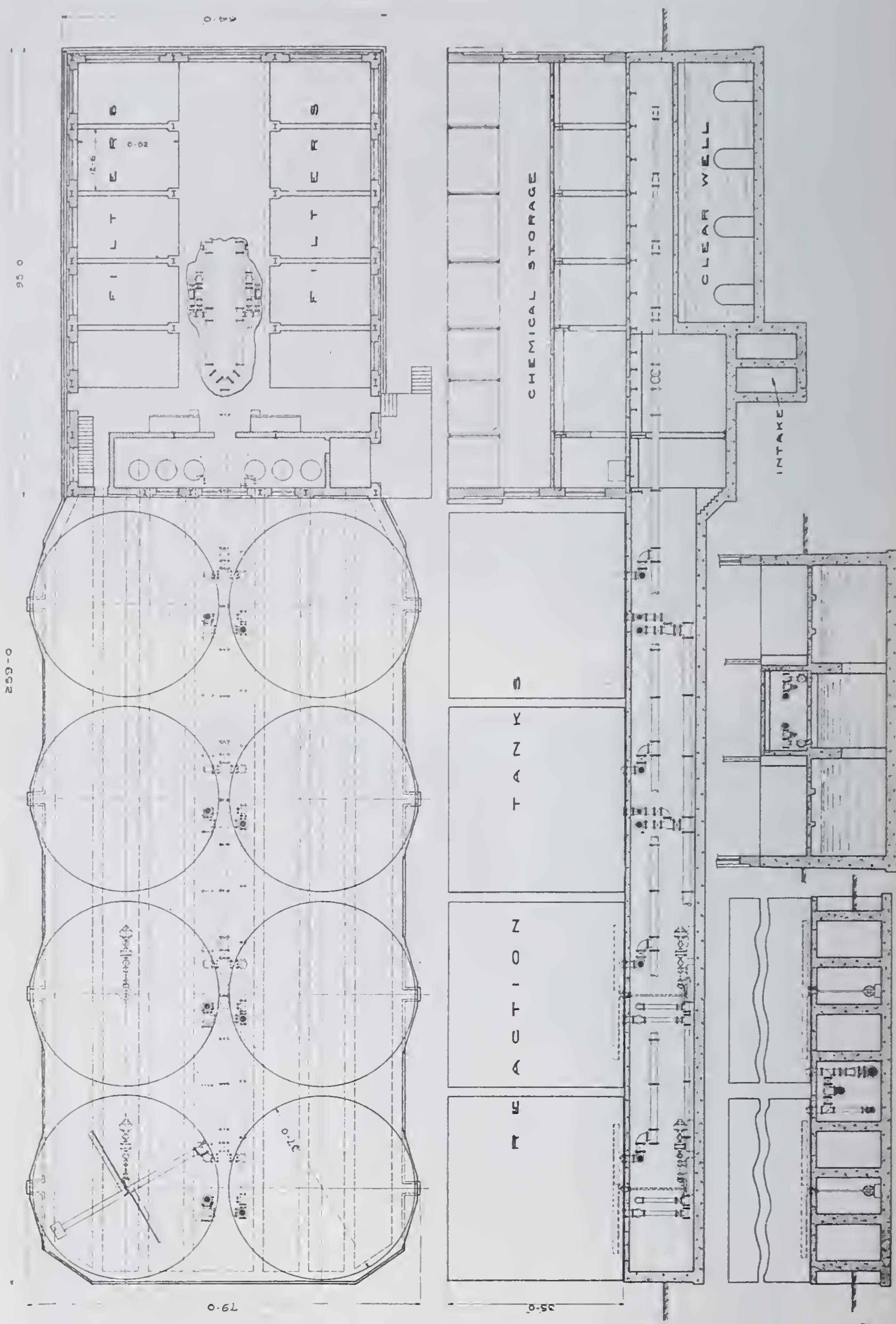


Fig. 5. Plan and Elevation of Installation.

Fig. 6. View over Top of Reaction and Settling Tanks.

Fig. 7. View across Filters.

DISCUSSION

Mr. H. B. Mann:* That two grains, approximately, of sodium carbonate seems to be about the same in all analyses. Would Mr. McKee tell us if that is maintained at that point in order to get proper conditions in the boiler or is it in relation to the chemical treatment of the water?

Mr. S. H. McKee: We have analyses of the treatment taken right along but the analyses I have shown are very recent. They compare very favorably with the average analyses taken. We take analyses for each tank treatment and the results are very uniform.

Mr. B. A. Ludgate:† I would like to know if the quality of the water as a boiler water has been appreciably improved since the installation of the Milton reservoir?

Mr. S. H. McKee: There has been an improvement, as I have stated, in the summer months. Before the Milton reservoir was put in operation the ordinary river flow in the summer time was about 10 000 000 gallons per day, but, with the addition of the reservoir, the aim is to keep this at 80 000 000 gallons per day. Our own plants, for instance, previous to the installation of the Milton reservoir pumped the river flow at least 15 times on its passage through the city; so, while there is not much difference in the analyses of the water, there is a lot of difference in the quantity. The use of this water for condensing purposes has been a great problem, as the temperature of the water in the river previous to the installation of the Milton reservoir was as high as 135 degrees F. Even now, it runs 100 degrees F. in the summer time.

Mr. Everts: How often do you have to turbine the boilers now?

*Sales Engineer, Dravo-Doyle Co., Pittsburgh.

†P. & L. E. R. R., Pittsburgh.

Mr. S. H. McKee: We turbine them now, every six weeks or two months. Some of our boilers do not require turbining that often. They are, apparently, staying fairly clean. The largest amount of scale we have gotten out since the plant has been in operation has been about 1200 pounds per boiler. The system has been in operation only since last July and, in fact, the last of our plants are just going on the system, so we still have to contend with the scale in the boiler feed lines, which is loosening up. We have even had the pressure pipes to recorders on our Venturi meters clogged up with scale. About two months, I would say, is our average cleaning period, but we expect to improve this.

Mr. Everts: Some plants around here claim six months.

Mr. S. H. McKee: As I said, our system has not been tried out long enough to get the best results, but it is improving every day. It does not take nearly as long to clean a boiler as it formerly took, as we are cleaning our worst cases now in 18 hours, as compared with 40 hours under former conditions. It is not necessary to keep a regular cleaning gang now, as formerly.

Mr. Everts: Do you notice any difference in maintenance costs?

Mr. S. H. McKee: Our system has not been in operation long enough to tell what our maintenance costs are. We have not had an opportunity to study this matter as yet, neither can we tell how much coal we are saving. We will be able to tell this a little later.

Mr. Everts: You are pretty sure you are saving some coal?

Mr. S. H. McKee: I cannot see why we don't. We do not have to heat up the scale or heat through the scale.

Mr. B. A. Ludgate: Have your observations shown that corrosion and pitting of boiler tubes has decreased since the installation of the Milton reservoir?

Mr. S. H. McKee: Yes, because we are free from acids in the water from this treatment.

Mr. B. A. Ludgate: Have your observations shown that a strong alkali water is injurious to the boilers?

Mr. S. H. McKee: I cannot say that they have. I have not heard of anything like that.

Mr. B. A. Ludgate: Have you made any study of the amount of free carbonic acid gas contained in waters, and its effect on boilers?

Mr. S. H. McKee: No, I have not. I am not a chemist, but a mechanical engineer.

Mr. R. M. Rush:* I have seen the plant of the Republic Iron & Steel Company, and I was very much interested in several things. One was the simplicity of the condensing equipment on their turbine-driven pumps. Mr. McKee mentioned that surface condensers were used. You know they are not used in raw water very much in this district; but he could use the surface condenser here on account of the purified water.

The air pump is one of the steam nozzle affairs that have no moving parts. The steam that is used to eject the air, as I recall it, is condensed by the condensate and that means that the heat in that steam used by the steam nozzle is conserved as the condensate goes to the clear water pump suction line and then on to the boiler feed-water heaters. The condensing system is thus very simple because there are no moving parts and very efficient because all the heat in the steam is used.

There is another thing. I have watched the water in the river at Youngstown for many years. The company I represent has supplied over fifty steam turbines to drive pumps in the city of Youngstown. I do not believe the people in Pittsburgh know how bad the water is. We think water here is pretty bad but in

*District Manager, Kerr Turbine Co., Pittsburgh.

Youngstown in the summer it is nothing but mud, and the water goes into this plant as a rather thin mud and comes out as clear as crystal.

I would like to know if Mr. McKee can tell us about the cost of the entire installation.

Mr. S. H. McKee: I would not care to give the cost of the installation.

Mr. R. M. Rush: How about the cost of treating the water?

Mr. S. H. McKee: It is costing us about eight cents per thousand gallons at the present time. Under present conditions we are operating only about 30 000 boiler horse-power. We expect to cut down to 6½ cents when we are operating 50 000 boiler horse-power.

Mr. B. A. Ludgate: Does that include maintenance and depreciation?

Mr. S. H. McKee: It includes complete operating costs, maintenance, etc., but does not include depreciation.

Mr. J. C. Hobbs:* I have been trying to get our chemist to ask Mr. McKee how often they blow the boilers down and about how high the concentration reaches.

Mr. S. H. McKee: I cannot answer that. It will be necessary for me to look the matter up and let you know.

Mr. J. C. Hobbs: Did the installing of this water softener system show any appreciable affect on the amount of foaming done by the boilers? Have you had any tube trouble due to the throwing down of old scale too rapidly?

Mr. S. H. McKee: Not that I know of. The plant was started in July of last year and was running steadily the rest of the year, but I did not hear of any trouble from that source from Mr. Emmons, our efficiency engineer. Had it occurred, I believe I would have heard of it.

*Assistant to Superintendent of Power Stations, Duquesne Light Co., Pittsburgh.

Mr. J. C. Hobbs: In this connection I might contribute a little evidence obtained from the same kind of a softening system. Before the softener was put into use, it was thought that there would be a lot of tube failures due to the loosening up of scale, which some felt was plugging up leaks; also tube failures due to the accumulation of scale in such quantities as to restrict or entirely stop the circulation. As a matter of fact, very few of the large stock of spare tubes, bought to take care of the trouble, have been needed.

Mr. Max Hecht:* I would like to ask what type of boilers are in service at the Republic plant.

Mr. S. H. McKee: Most of our boilers are Stirling, class F-29, 464 horse-power, except the boilers for our new blast-furnace plant, which are Stirling, class M-46, 1262 horse-power. We are, however, putting in at present four 1130-horse-power Babcock & Wilcox boilers.

Mr. J. C. Hobbs: Have you had any trouble from priming, and, if so, has it left any deposit in the superheaters, or in the steam-using apparatus?

Mr. S. H. McKee: That is something along the line of Mr. Mann's question. To tell you the truth, I cannot tell you the experience we have had along that line. My work keeps me pretty close to the office, although I am in fairly close touch with the operating end, and I have not heard of any particular trouble along those lines.

Mr. J. C. Hobbs: Are the Stirling boilers using this feed-water equipped with a middle-drum or rear-drum steam off-take?

Mr. S. H. McKee: We have a middle drum, and I believe the Sheet & Tube Company has been trying out a rear-drum steam connection.

Mr. Hildner: In connection with the use of this water for locomotives, as against the use of the same water for stationary boilers, do you have any experience with locomotive boilers?

*Chemist, Duquesne Light Co., Pittsburgh.

Mr. S. H. McKee: We operate about 15 standard-gage locomotives and several narrow-gage. Since the system was started, we cut off from the supply we had been using, which was furnished by a company from Youngstown, and was not from the Mahoning River, and I have not heard of any particular difficulty along these lines.

Mr. L. F. W. Hildner:* If the mills use this water so often what do the people of Youngstown do for water?

Mr. S. H. McKee: It is really better for them because, by reason of its temperature, it has a tendency to kill the "bugs."

Mr. L. F. W. Hildner: Where do they get their water?

Mr. S. H. McKee: Right from the Mahoning River.

Mr. L. B. Duff, III:† This question is more or less off the line of the operation of the water softener but, in the construction of the clear wells and other portions of the structure necessary to be water-proofed, what system of water-proofing do they use?

Mr. S. H. McKee: I think a lime treatment.

Mr. L. B. Duff, III: Not a membrane treatment?

Mr. S. H. McKee: No, just a lime treatment. We got particularly good results. The construction was handled by our department and I am quite sure we use a lime treatment.

Mr. L. F. W. Hildner: Hydrate of lime?

Mr. S. H. McKee: Yes. During the high water of 1913, the river was six feet above practically all our plant yard levels, so this building was set up seven feet six inches above yard level, and water-proofed. We have not had any real high water since that time, but we are right on the river bank and below river level and the results seem to justify our method, as we have not had any trouble from that source.

*Vice-President and Chief Engineer, Pittsburgh Bridge & Iron Works, Rochester, Pa.

†Civil Engineer, Pittsburgh.

Mr. L. B. Duff, III: I was wondering if you were able to keep out the water without a membrane reinforcement.

Mr. S. H. McKee: Yes.

Mr. L. B. Duff, III: I have known soap and alum to be used successfully for a small installation.

Mr. C. W. Crider:* If he was getting 1200 pounds of scale out of each boiler, then it would seem that all the old scale was still coming down, because I know of a boiler-house installation using the same kind of a feed-water treating system where all of the tubes are turbined only about twice each year, and only a small bucket full of scale is obtained. Also, with about 23 000 tubes in service, only one new tube has been put in during the last six months.

Mr. S. H. McKee: Our plant has not been run long enough to get the results from boilers that we should get, but this matter is improving all the time. Some of the boilers do not need turbine cleaning.

Mr. L. F. W. Hildner: How many men does it take to operate a plant of that kind?

Mr. S. H. McKee: Three men per day, and three men per night.

Mr. Max Hecht: Does Mr. McKee mean three men per turn or three men per 24 hours, and does that include all pumping operations or just treatment?

Mr. S. H. McKee: Three men per turn. The engineer, the man who weighs and mixes the reagents, and a kind of general operator who makes the analyses. This plant operates, however, under the Efficiency Department and it is the custom for one of the efficiency men to drop in in the morning and late in the afternoon and see how the plant is doing. The Efficiency Department has kept in very close touch with this plant and I think the results that we have obtained justify their efforts.

*Superintendent Boiler Room, Duquesne Light Co., Pittsburgh.

Mr. S. E. Duff: I would like to speak for the great majority of the audience that perhaps do not feel like making many inquiries by saying that Mr. McKee has certainly presented an interesting subject and presented it in a precise, logical manner, to which we are beginning to become accustomed in our engineering societies. That is perhaps a queer remark, but what I mean to say is that I have noticed in attending these meetings and discussions through a long series of years that we are beginning to get papers which start at the beginning, sketch every detail in logical sequence, and handle the subject completely—and I think we have had such a one to-night. As a source of information to people who are not particularly expert in this subject, this sort of treatment is worth very much more than papers which are presented in a more careless manner, as many of them have been. I think that is something we should all recognize.

Mr. McKee has been very kind in answering questions frankly. Some of them he told us he would not answer, but costs are rather a forbidden subject anyway. What I was going to say is that Mr. McKee has shown a great deal of courtesy in coming away over here and telling us all these things; and he has gone farther than that and invited us to come over and see his plant. I would move a vote of thanks to him for his very good paper.

POWER PIPING

By J. Roy Tanner* and George J. Stuart†

OUTLINE

General

Progress in the Art

Pressures. Superheat. Standardization. Progress in Manufacture

Materials

Effect of Superheated Steam

Pipe Joints

Details of Construction

Valves. Fittings. Wrought Pipe. Bends. Welding and Swaging. Cast-Iron Pipe. Bolts. Gaskets

Drawings and Specifications

Design

Pipe Sizes. Headers. Branches. Other Details

GENERAL

When the writers first contemplated the project of contributing to the sum of engineering knowledge concerning the subject of "Piping," the first impulse was to pray to be excused, because the subject seemed so general in character, and withal so commonplace, that it seemed impossible to cover it within the scope of a paper such as this, when volumes might be written on it.

It is a fact, however, that, concerning the subject of piping systems, their design, the proper selection of materials, and of apparatus with which to fabricate them, there is a surprising un-

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familiarity on the part of many engineers otherwise well informed and up to date.

This may be due to the rapid changes and developments in power generating machinery, through the increased pressures used and the extension of the use of superheated steam, which has necessarily completely changed the power piping industry from a mechanical trade to a specialized branch of engineering, when taken to include the design and manufacture of all the material used.

Again, when it is recalled that pipe-lines convey steam, water both for service and hydraulic power, air, gas, and various chemicals in liquid form, it is realized that the general piping contractor is brought into contact with, and must assist in solving, some of the problems of practically every branch of manufacturing.

It was this thought which led the writers to hope that even in the limited time at their disposal they might, by sticking to the high spots of the average commercial lay-out for a steam driven plant, summarize and emphasize some points which would tend towards safe practice without undue cost; and, further, to solicit attention to the fact that it is the piping which keeps the machines going, and that the piping system merits the most careful thought and attention. No plant is stronger than its weakest pipe, providing that pipe is a link in the chain from boiler to condenser.

A set of drawings coming to our attention recently, included and specified a globe-valve in an engine exhaust, and another had an unbalanced slip expansion joint in the middle of a high-pressure steam header and not a thing to resist the unbalanced thrust except 15 pounds atmospheric pressure.

Both drawings came from good organizations—very careful and even critical about everything else, but failing to realize the importance of their piping designs.

Another engineer installed a globe-valve of large size in a position where a moment's consideration would have shown him that, though the valve and stem were strong enough to hold the pressure, a lever four or five feet long would be required on the stem, to force the valve shut by man power, and a very strong man would be needed on the lever.

The confining of this paper to the commercial lay-out does not mean that, under certain conditions, the utmost that can be done in the way of refinement and finish is not justifiable; as, for instance, certain large installations where everything is on the same plane, or material for naval use, etc., but for the plant which must pay its way, and contribute to its owner's profit it will be found that the manufacturers of power piping material have kept pace with the manufacturers of power machinery, and that the standard lines which they have developed for the different kinds of service are good, and safe to use within the limits of pressure and service which any of the standard catalogues prescribe.

PROGRESS IN THE ART

The development of power generating machinery referred to has compelled simultaneous progress in the power piping industry. Pressures have doubled and tripled. Sizes required, especially for low-pressure, condenser, and water piping have increased many fold. Superheated steam meant new designs and new materials As a result, the pipe fitter of our recollection, with his small shop, a few tools, and a cutting-and-threading machine or two, has been transformed into a manufacturer with all of the foundries—iron, steel, and brass—pattern shop, machine-shops, and pipe shops full of special machinery, and engineering and construction organizations of trained specialists.

Not much more than a decade ago the largest single contract for piping amounted to around a hundred thousand dollars. To-day plants with half a million dollars worth of piping placed in a single contract are not uncommon and million dollar jobs are not unknown.

PRESSURES

The steam pressures carried have gradually increased until the present "extra heavy" material used for high-pressure steam is designed for 250 pounds working pressure. The tendency on the large installation is still upward. Material designed for 350 pounds and superheat is in use with success, but has not yet had wide enough application to be reduced to standard practice.

SUPERHEAT

The steam-turbine has changed practice by bringing superheated steam from occasional into extensive use. It developed, shortly after the introduction of superheat, that some of the materials in use for saturated steam would not stand the higher temperatures and it was necessary to find substitutes for cast-iron and bronze. The former was replaced by cast-steel, and the latter to a great extent by nickel alloys—notably "Monel metal"—with substantially the same thermal expansion as steel.

At first, there were very great difficulties in obtaining steel castings suitable for valves and fittings and, in order to be assured of castings sound at the point of juncture between the heavier flange section and the lighter shell section, many engineers drew their specifications calling for a finish strip, in each opening of cast-steel fittings, to a depth of about twice the flange thickness. This had to be machined out to the bore dimension of the fitting, thus uncovering any defects which might exist.

Foundry practice improved, however, and it soon became possible to make or obtain pipe castings with reasonable certainty of soundness.

The evolution of stems and mountings to withstand this service was also satisfactory. Some early installations, after failures of bronze, went back to first principles and used stems of steel with no seat or disk mountings. Nickel steel was tried but this meant forgings. Nickel was also used. The discovery and development of "Monel metal" has given us a material known to be safe for use with steam pressures up to 250 pounds and the superheating used at this pressure.

The effect of superheated steam upon materials for piping will be touched upon later.

STANDARDIZATION

The importance of standardization as a factor in the industrial position of this country to-day is nowhere better illustrated than in this industry under discussion. A few years ago each manufacturer had his own standard for the dimensions of flanges, fittings, and drilling templets. This compelled the large users of

piping, such as steel mills, to adopt something which was very likely to be original. Also, about the first thing an engineer did after putting up his sign, was to calculate and design his own piping standard. There was a tremendous amount of brain power consumed which can now be diverted to other purposes. The effect of this confusion was that manufacturing in all that the word implies was impossible because changes of flange sizes or center to face had to be made at frequent intervals. This condition prevailed long after the American Society of Mechanical Engineers, in 1894, adopted, after conferring with the Master Steam and Hot Water Fitters and some of the manufacturers, a standard flange templet which subsequently became the "A. S. M. E. Standard" used for lower pressures, along with the "Manufacturers' Standard" for extra heavy material, in 1901, and it was several years after this before the flange situation became clarified.

Some time after 1910 a group of manufacturers of valves and fittings formed an organization called the "Committee of Manufacturers on Standardization of Valves and Fittings," and began the work of designing a completely standardized line of fittings, including center to face, and shell thickness. This work was completed and published and about a year later revised to meet the views of the American Society of Mechanical Engineers regarding the bolting of extra heavy flanges larger than 12-inch. This revision was accepted at a conference in Washington by representatives of the United States Government, the American Society of Mechanical Engineers, the Master Steam and Hot Water Fitters, and the Manufacturers' Committee. The American Society of Mechanical Engineers adopted the report of its Committee—compiled under the direction of the late Mr. H. G. Stott—and thus made effective the "American Standard for Pipe Flanges, Fittings and their Bolting," to become effective January 1, 1914. The report of this Committee was a masterpiece of complete analysis.

The American Standard consisted of specifications for "Standard" material up to 125 pounds pressure and "Extra Heavy" material up to 250 pounds pressure.

The American Society of Mechanical Engineers and the Manufacturers subsequently collaborated in standardizing hydraulic flanges up to 3000 pounds pressure, culminating in the adoption of a report in December 1918.

Economy demanded the use of a lighter design than that specified for 125 pounds, for use on low-pressure water, condenser service, etc., and the American Society of Mechanical Engineers has made a recommendation for lighter shells and smaller bolts than the American 125-pound standard, and flanges of the same diameter, thickness, and bolt spacing. The Manufacturers' Committee, however, is considering the advisability of using a thinner flange for this service, owing to the foundry difficulties attending such a great change in section, and may request the American Society of Mechanical Engineers to reconsider this point.

Some work had been done by the Manufacturers' Committee to determine the feasibility of standardizing valve dimensions from center to face, but with no results. In the fall of 1918, when the Emergency Fleet Corporation was struggling with the problem of a design for the piping of fabricated ships—the standardizing Engineer for the Emergency Fleet Corporation—Mr. John A. Stevens, who played a large part in formulating the Boiler Code of the American Society of Mechanical Engineers—attacked the problem of interchangeable dimensions for the valves to be used by the fleet, calling to Philadelphia engineering representatives of all the large valve manufacturers and, had it not been for the armistice, the fleet would probably by now have had a standard center to face dimension for every valve to be used by them on shipboard. It is, therefore, not impossible that at some future date, we may even have interchangeable face to face dimensions of valves.

A large amount of standardization work has been done by the Power Piping Society, an organization of fabricators and erectors. The "Standard Specifications for Power Piping" adopted by the Society in 1915 was the result of the experiences of a group of men who had installed a considerable part of the power piping in this country, and can therefore be accepted as safe modern practice.

Thus out of chaos has come some degree of order, for the benefit of the user of pipe, valves, and fittings.

PROGRESS IN MANUFACTURE

In order to meet demands more exacting from year to year, it has been necessary for the up-to-date manufacturer to introduce every precaution of the best shop and foundry practice, inspection and test; for he realizes that upon the excellence of his product may depend not only the safety of property but also of lives.

MATERIALS

Wrought Steel. In power piping, wrought steel appears as pipe, flanges, valve-stems, bolts and hangers. The "skelp" or plate out of which pipe is made in the tube mill is of somewhat lower tensile strength than the steel used on other piping construction—probably about 50 000 pounds per square inch.

Wrought-Iron. In sizes up to and including 12 inches, pipe of wrought-iron is in wide use.

Rolled Bronze. This material plays an important part in valve construction. It is obtainable in finished bars of diameters sufficient to cover the whole range of sizes for outside screw gate-valves, and of a tensile strength from 55 000 to 60 000 pounds per square inch.

Gray Iron. For valve and fitting work this material should be of close grain and of not less than 20 000 pounds per square inch tensile strength.

Semi-Steel. This material has come into wide use for high-pressure saturated steam. It is of very close grain and much stronger than gray iron. It should possess a tensile strength of not less than 30 000 pounds per square inch.

Cast Bronze. The alloys of this group play a very important part in valve manufacture. Various mixtures of different properties are used for different purposes, some hard for wearing purposes, as "steam metal" and others tough and strong as "navy bronze" manganese bronze, etc.

Cast-Steel. Inasmuch as manufacturers use the same or equivalent patterns for cast-steel or semi-steel, in power piping, the exact physical properties of the metal are of less importance than the soundness of castings, which is paramount. However, the metal should meet the requirements of the American Society for Testing Materials for "Medium Castings." To obtain the ductility specified, which is the most important quality, thorough annealing is necessary.

"Monel Metal." This material is obtained for valve work either in casting form or in rolled bars. The former is used for mountings and the latter for stems under superheat. The metal is a natural alloy containing an average of about 68 per cent. nickel, 30 per cent. copper and a small percentage of iron. Physically, it has about the same properties as the steel used for valve work, either cast or rolled, and the coefficient of expansion is within about 10 per cent. of being the same.

EFFECT OF SUPERHEATED STEAM

In general, all of the materials enumerated above have proven unsuitable for superheated steam except steel, wrought-iron, and "Monel metal." Superheat had not long been applied to steam for power purposes until failures began to appear and the reasons therefor are believed to be apparent in view of the following facts. For the figures given for the behavior of the various metals under tensile stress we are indebted to the Crane Company who published in the *Valve World,* in January 1913, the results of an exhaustive series of tests to determine the properties of metals and alloys under high temperatures. Wrought steel and wrought-iron have given satisfactory service under superheat conditions. No figures are available for their behavior at high temperatures but it is safe to assume that they are similar in this respect to cast-steel.

Cold rolled steel is of interest because of its use for valve-stems. Samples tested cold and showing a tensile strength averaging 82 800 with 76 800 elastic limit remained with practically constant characteristics up to 525 degrees F. At 600 degrees, tensile strength was still high but the elastic limit dropped to 54 275. Both properties fell off rapidly at higher temperatures.

Rolled bronze of 54 450 and 45 000 tensile strength and elastic limit, respectively, drops off rapidly from the start, and at 600 degrees the corresponding figures are down to 35 050 and 23 735 for the tensile strength and elastic limit, respectively. These figures point to the unsuitability of this material for superheat, in addition to difficulties from the greater coefficient of expansion.

Gray iron of 22 000 pounds tensile strength remains practically unchanged up to 1000 degrees, and semi-steel up to nearly 900 degrees, so were it not for another property of both of these metals they would be almost ideal. The trouble lies in the extremely low elastic limit and the fact that permanent set begins at low stress; together with expansion and contraction when the metal is alternately heated and cooled. As each contraction is slightly less than the preceding expansion, in course of time there is an appreciable growth in all dimensions and a weakening of the material. Instances of growth as great as one-fourth inch to the foot are not uncommon. This, of course, is fatal to valves, as the seats become so loose that they fairly drop out.

Up to 500 degrees F. cast-iron and semi-steel seem to behave satisfactorily if temperatures are constant, but the uncertainty of constant temperatures where superheaters are installed has led the writers to conclude that the only safe practice is to eliminate cast-iron and semi-steel in any installation where the steam passes through a superheater. It is true that valves of semi-steel with "Monel metal" mountings have worked successfully at temperatures above 500 degrees but the writers know of no such case where the operation was not continuous and the load practically constant. On the other hand, there are installations where lower temperatures with great fluctuation caused the same material to fail absolutely.

Cast bronze of 33 735 tensile strength and 25 035 elastic limit, behaves well up to 450 degrees, but at 600 degrees the figures drop to 23 150 tensile strength and 17 160 elastic limit, so that it is the safer proceeding to eliminate it under superheat.

Cast-steel of 73 325 pounds and 39 817 pounds tensile strength and elastic limit, respectively, holds up to 600 degrees to 67 366 pounds and 29 422 pounds tensile strength and elastic limit, respectively. At 720 degrees these properties become 58 713 pounds

and 33 313 pounds tensile strength and elastic limit, respectively. At 750 degrees they are 41 388 pounds and 27 223 pounds tensile strength and elastic limit, respectively. It is thus apparent that cast-steel is the metal best adapted to use with superheated steam, but with some of the higher temperatures now discussed, on account of the reduction in strength, very careful design will be required.

Cast "Monel metal" of 52 870 pounds and 30 088 pounds tensile strength and elastic limit, respectively, at 450 degrees changes to 47 200 pounds and 22 350 pounds tensile strength and elastic limit, respectively, and at 700 degrees to 41 787 pounds pounds and 21 700 pounds tensile strength and elastic limit, respectively. This behavior approximately parallels that of cast-steel and renders the combined use of these metals very satisfactory. To the knowledge of the writers, there has been no trouble encountered with temperatures below 600 degrees but above that point some difficulty, mainly mechanical, has occurred, though up to the present time there is no certainty that the use of "Monel metal" was blamable.

Rolled "Monel metal" of 104 900 pounds tensile strength and 78 350 pounds elastic limit, at 600 degrees, changes to 89 600 pounds and 57 950 pounds; and, at 750 degrees, to 67 600 pounds and 42 550 pounds.

PIPE JOINTS

A pipe system, consisting of numerous pieces, must be joined together in a way which gives security and tightness. The two broad classifications of joints are screwed and flanged. Screwed connections are always the rule in the smaller sizes for all purposes. The sizes for and above which flange joints are used in good practice are—for superheated steam, 2 inches; for saturated steam above 125 pounds, 2½ inches; for boiler feed, 2½ inches; for exhaust, 2½ inches; for low-pressure water, 2½ inches; for blow-off, 2 inches; and, for drains, 2½ inches.

The flange joints in common use for pipe are screwed, vanstone, expanded, and welded. Nothing in the light of experience as to cost or durability calls for the use of more than the first

two. Vanstone joints of course include all joints of the lap type. Slight differences in design are used by different manufacturers but the term includes the "Walmanco," "Cranelap," "Murdoch improved," "Atwood," etc.—all trade names for substantially the same construction. Whether reinforced or not, and whether round cornered or square cornered, is immateral to safety, providing two points are rigidly observed—the pipe must fit the flange accurately, and the lap must be turned over to the inside edges of the bolt holes.

For the different classes of service the following may be taken as safe practice:

Extra heavy screwed flanges should be refaced after being made up.

For all superheated steam, flanges six inches and larger should be high hub steel vanstoned; and for five inches and smaller, extra heavy steel screwed.

For saturated steam between 150 pounds and 250 pounds, inclusive, six inches and larger should be low hub steel vanstoned; and five inches and smaller should be extra heavy semi-steel screwed. There is no serious objection to making the screwed flanges of steel, but the proportions of the American Standard screwed flange are ample for this service in semi-steel.

For saturated steam between 125 pounds and 149 pounds inclusive, flanges 14 inches and larger should be extra heavy high hub semi-steel vanstoned and, for 12 inches and smaller, extra heavy semi-steel screwed. If desired the vanstone type may be used down to and including six inches.

For boiler feed and drain piping between 125 pounds and 250 pounds inclusive, flanges should be extra heavy semi-steel screwed.

For exhaust, suction, low-pressure water, and low-pressure drains, flanges 14 inches and larger should be cast-iron vanstoned, and 12 inches and smaller should be standard cast-iron screwed.

For blow-off, flanges should be extra heavy semi-steel screwed.

On all screwed work there should be a sufficient number of unions to facilitate repairs, and an excellent practice is to install one union adjacent to each screwed valve. Unions 1½ inches and larger should be flanged and below this size they should be screwed, gasketless, with non-corrosive seats.

DETAILS OF CONSTRUCTION

VALVES

Valves for shutting off the flow of fluids through pipes are of two general types—globe and gate. In general, gate-valves should be used, except where a throttling action is desired, in which case a valve of globe type should be used. Globe-valves are also preferable in sizes below ¾-inch.

Wherever possible in power piping, gate-valves should be of outside screw type so that a glance will tell whether they are open or closed. For underground work, the inside type is preferable on account of the protection afforded to the screw-threads. All outside screw valves should be back seated in their bonnets so that they may be repacked when wide open.

For Superheated Steam. Gate-valves two inches and larger should be extra heavy, outside screw pattern, with cast-steel bodies, bonnets, disks, and yokes, and "Monel metal" seats, disk rings, back seating bushings, and stems. Valves eight inches and larger should have by-passes.

Globe-valves and angle-valves of the same sizes should be similarly equipped.

Valves 1½ inches and smaller may be of nickel bronze or drop forged steel.

For Saturated Steam Between 150 Pounds and 250 Pounds Inclusive. Gate-valves 2½ inches and larger should be extra heavy, outside screw, semi-steel, with bronze mountings and bronze stems. Steel stems are permissible if cleanliness and attention are assured but, on account of decreased liability to sticking, it is believed that for live steam the bronze stems are worth the extra cost. By-passes should be used for sizes eight inches and larger.

Globe-valves and angle-valves should be of similar construction.

All valves two inches and smaller should be extra heavy bronze.

For Saturated Steam Between 125 Pounds and 149 Pounds Inclusive. Gate-valves of medium pattern, equipped the same as for 150 pounds to 250 pounds saturated steam are permissible.

Globe-valves and angle-valves 2½ inches and larger should be extra heavy, as should also all valves two inches and smaller.

For Boiler Feed Between 125 Pounds and 250 Pounds Inclusive. All valves 2½ inches and larger should be extra heavy semi-steel completely bronze mounted, and smaller sizes, extra heavy bronze.

For Exhaust. Gate-valves 14 inches and larger should be low pressure, outside screw, cast-iron, bronze mounted, with steel stems. Standard pattern valves, similarly equipped, should be used from 2½ inches to 12 inches inclusive. Below 2½ inches, standard brass valves are sufficient.

For Suction and Low-Pressure Water. The specifications should be the same as for exhaust, except that stems should be of bronze.

Non-Return Valves. These should be specified as to materials the same as in the foregoing for steam.

FITTINGS

The different lines of commercial fittings are extra heavy cast-steel, extra heavy semi-steel, standard cast-iron, and low-pressure cast-iron. The latter extend from 14 inches upward, inclusive.

WROUGHT PIPE

The classes of wrought pipe used for power piping are standard and extra strong. Pipe comes from the mill in varying lengths averaging about 18 feet. The customary division line between butt-welded and lap-welded sizes is between 3 and 3½ inches for standard pipe, and between 2 and 2½ inches for extra strong.

For Steam Between 150 Pounds and 250 Pounds Inclusive. Pipe 7 inches and smaller should be full weight; 8-inch should

be 28.55 pounds per foot; 9-inch, 33.90 pounds; 10-inch, 40.48 pounds; 12-inch, 49.56 pounds; 14- to 20-inch, inclusive, ⅜-inch; and 22- to 24-inch, inclusive, 7/16-inch.

For Steam Between 125 Pounds and 149 Pounds Inclusive. Pipe 7 inches and smaller should be full weight; 8-inch, 24.69 pounds; 9-inch, 33.90 pounds; 10-inch, 34.24 pounds; 12-inch, 43.77 pounds; 14- to 20-inch, inclusive, 5/16-inch; and 22- to 24-inch, inclusive, ⅜-inch.

Boiler Feed. Pipe should be extra strong from 150 to 250 pounds inclusive, and may be lighter for lower pressures unless the additional weight is advisable to resist corrosion.

Exhaust Piping. Pipe should be the same as for steam from 125 pounds to 149 pounds, up to and including 12 inches. Between 14 inches and 18 inches inclusive ¼ inch pipe is sufficient and for 20 inches and larger the lightest card weight may be used.

Blow-Off Piping. This should all be extra strong.

BENDS

Bent pipe is always preferable to fittings for changes in alignment. When possible, radii should be not less than six diameters of the pipe.

WELDING AND SWAGING

The use of welded branches, line welds, and swages have made possible almost the entire elimination of fittings from steam headers, with a consequent decrease in the number of joints and also in most cases a decrease in cost. The line weld permits pipe to be joined up to the limit of shipping dimensions, which for single cars is two full lengths.

The standard reductions in diameter by swaging are 16-inch to 10-inch and intermediate reductions; 18-inch to 12-inch; 20-inch to 14-inch; 22-inch to 16-inch; and 24-inch to 18-inch.

CAST-IRON PIPE

Cast-iron pipe is used mainly for suction and low-pressure water, and occasionally for exhaust purposes. The pipe corresponding to "Class A" specified by the American Water Works

Association is suitable for these purposes. As a rule, underground construction is bell and spigot, which is better than flanged for this purpose on account of its greater flexibility under unequal settlement.

BOLTS

All bolts in a system should have United States Standard, cold punched, chamfered and trimmed nuts, for the reason that the wrench equipment used by erectors has been standardized in this respect, and time can be saved by adhering to this system. Also the uniformity of the cold punched nuts is of material assistance to the fitter in pulling up the joints on the work.

GASKETS

Many and various are the forms of gaskets made. In general, a thin gasket is preferable to a thick one, and for all purposes except for vacuum service, they should be "ring" gaskets, extending only to the inside edges of bolt holes. Under vacuum the custom is to make them the full diameter of the flange and to punch the holes.

For superheated steam, steel or superheat sheet—such as "Tauril," "Durabla," etc.—give satisfaction.

For saturated steam, boiler feed and blow-off, any of the sheet packings equal to "Rainbow," the old standard, or corrugated copper, are in common use.

For exhaust sheet, the equivalent of "Rainbow" is satisfactory.

For water, nothing has proven better than cloth inserted rubber.

Gaskets 1/16-inch thick are good up to 12 inches, and above that size it is well to use 3/32-inch sheet.

The failures we have noted have been mostly when copper has been used under superheat, where asbestos or packing containing asbestos has been used on wet steam or water, and where rubber has been used where oil could decompose it.

DRAWINGS AND SPECIFICATIONS

A good set of piping drawings in conjunction with well-drawn specifications should give sufficient detail to enable contractors readily to make intelligent estimates of cost, to develop a clear-cut proposal leaving no unsettled points leading to later misunderstandings, and to furnish all information necessary to fabricate and erect the complete job.

Frequently, proposal drawings are made for the purpose of securing bids only, with just sufficient information to enable contractors to approximate the cost. Drawings of this kind leave to the imagination of the estimator such items as drains, all smaller pipe lines—say two-inch and smaller—hangers and supports, grade of material to be used; and, in some cases, where elevations have not been shown, he is forced to guess the length of pipes costing several dollars per foot.

This practice should be resorted to only for estimates to be used for securing appropriations and then a liberal allowance should be made for contingencies.

There is quite a narrow dividing line between too little and too much detail on a piping drawing. It is possible to go too much into detail. For example, it is not uncommon to see on piping drawings the center to face of fitting and the length of pipes, the draftsman however making no allowance for gaskets or for cutting the pipes short to allow for expansion. Confusion, of course, is the result. Bills of material almost invariably lead to confusion when used in conjunction with a piping drawing. A bill of material agreeing exactly with a piping plan of any considerable size is very rare indeed.

The question, therefore, naturally arises as to just how far one should go into details. To enumerate all of the things to do and the things not to do would be beyond the scope of this paper, but a few general statements may be of service.

Do not attempt to show too many pipe lines on one drawing. On all lines two inches and larger, show the size and location of all fittings, valves, anchors, supports, and drain taps, and on all smaller lines indicate in general how they shall run; then describe them in the specifications. The specifications should state the limits of the contract. This embraces the question as to whether

the piping contractor shall furnish the throttle valves, blow-off valves, pump governors, boiler-feed valves, and regulators, or any piece of apparatus that is commonly purchased separately or furnished by other contractors, yet related to the piping. If furnished by others, the specifications should state who shall make the installation.

As previously stated, the location of supports and anchors should be indicated on drawings and, if conditions are such that standard supports and anchors cannot be used, a set of building drawings should accompany the piping drawings and the specifications should call attention to the special cases.

If close clearances are encountered, large-scale drawings should be made and, if it is found that standard fittings cannot be used, details of the specials should be made.

If special equipment, with which piping contractors in general are not familiar—such as CO_2 recorders, steam-meters, and the like—are to be piped, the specifications should describe the piping and service in detail.

The specification should state the working pressures and degree of superheat, if any. (It may seem strange but this very important detail is often neglected.) They should also set forth the method of attaching the flanges and of what material the flanges are to be made. Whether the valves shall be inside or outside screw should be stated. There are so many details of this nature that if the engineer is not familiar with them he will do well to study carefully one of the several good catalogues and power piping specifications previously referred to and, if still in doubt, consult a reliable contractor who will gladly give him an honest opinion based on his experience in plants of a similar nature.

Another method resorted to in making inquiries for piping work is to show in general what is required and to ask the piping contractors to figure on material which in their judgment will produce a first-class job.

The success of this method depends entirely upon who gets the job. If the contractor is experienced and conscientious the

work will be satisfactory. In general, however, it is well to require the bidder to specify before closing the contract, exactly what he expects to furnish.

DESIGN

PIPE SIZES

The determination of the proper sizes of pipes necessary to transmit a given quantity of power is, of course, of prime importance and should be given very careful study. Not so long ago, velocities of 6000 feet per minute in live steam lines and 4000 feet per minute in exhaust lines were considered standard. Later, however, with the advent of the steam-turbine, having comparatively steady flow, these velocities have risen to 12 000 feet, and quite often to 15 000 feet per minute in live steam lines, and 24 000 feet per minute in short vacuum lines between turbines and condensers, without an excessive drop in pressure.

The above figures, of course, apply to turbine installations. If reciprocating units are used the velocity must be kept lower. Here the question of pulsation enters largely into the problem and, if the reciprocating units are large and the cut-off early, large receivers should be installed and the velocity kept to a minimum.

The method of determining the pipe size entirely from the velocity of the steam is not considered as good practice as to base results on the drop in pressure, keeping in mind also the loss of heat by radiation. Obviously, the larger the pipe used to pass a given quantity of steam the less the drop in pressure and the greater the heat loss, hence a pipe may be made so large that the gain is entirely offset by the loss by radiation and additional cost of pipe. It will be seen that it is impossible to set down any offhand or rule-of-thumb method of pipe-size determination which takes into consideration the velocity, length, pulsation, and heat loss.

All of these variables are considered in standard engineering handbooks, and reference should be made to these sources of information.

HEADERS

After determining the pipe sizes, the location of the headers is probably the next natural determination to be made. The relative location of boiler room and turbine or engine-room will enter largely into this problem. Some of the late power-plants have placed their steam headers just above the boiler-room floor with long drop legs from the boilers. This places the valves in an accessible position, gives an abundance of flexibility to the branch lines and, where sufficient floor space is available, makes an ideal arrangement. There is also a tendency at the present time to make the header in several short units and to connect these units by means of expansion bends of liberal size. This method has something to recommend it if exceedingly high temperatures prevail but has the disadvantage of increasing the drop in pressure due to the tortuous path of the steam. This type is also located just above the boiler-room floor and is the type in use in one of the latest and most up-to-the-minute power-houses.

Another type of header and one in very common use is that running the full length of the boiler room or engine-room and at about the elevation of the top of the boilers. One disadvantage of this header is that the valves are quite inaccessible. There are, however, more headers of this type in use than any other. It is a decided improvement to this header to provide a substantial walk way running the length of the header, or to equip the valves with chain-wheels and chains within reach from the floor.

The question of duplicate headers and loop lines is one that has had much discussion among designers; some holding them to be worth while, while others avoid them. To the writers, it appears to be a question as to whether or not the plant can afford to cut off a portion of its load in an emergency or if the uncrippled part of the plant can carry sufficient overload for a limited time. An argument recently advanced against the duplicate system with its attending valves was that after the system had been in service for some time the valves could not be depended upon to isolate the defective section of piping. This objection is sometimes valid. In several cases where leaky gate-valves were investigated, it was found that the trouble was entirely due to sediment in the valves. To prevent this and also to increase the efficiency of the

boilers, one of the power-plants previously mentioned is distilling all make-up water with the result that valves taken apart after two years of service were found to be absolutely clean.

Having determined the type and location of headers, the branches to and from them should be considered. Drainage and flexibility are here the determining factors.

BRANCHES

There should always be two valves in each branch to or from a header and care must be taken that the water pockets thus formed can be readily drained. If the branch is taken from the side of the header, with a square bend and a separator in the drop leg, the drainage can be more readily taken care of than if the branch is taken from the top of the header with a U-bend and separator to the engine. This latter method, however, has the advantage of offering less liability to picking up a slug of water from the header and the further advantage of taking off the steam at the dryest point. The same principles apply to boiler branches, and the choice as to which of the two methods shall be used depends upon the skill of those who are to operate the plant. If the plant is to be a high-class one operated by men thoroughly competent and well drilled, the branches should be taken from the top of the header but, if there is a probability that the valves will be operated by less skilled men, the more simple arrangement of draining makes the side branch preferable.

It has become almost universal practice to install a non-return valve on each boiler. In the selection of non-return valves, care should be exercised to see that they are provided with proper dash-pots to prevent hammering and that the dash-pots are so designed that sediment from the steam will not foul them and cause sticking.

The second—and equally important—point to consider in designing branches is their flexibility in order to take care of expansion and contraction. Many devices known as expansion joints have been marketed but none of them will give the year-in-and-year-out service of the pipe bend. This fact is so well recognized by piping designers that it seems superfluous to mention the expansion joint while speaking of high-pressure piping. Expansion

joints have their use in other lines, however, and brief references will be made to them later.

The modern boiler branch seems to have been modeled after a dog's hind leg and a pig's tail—the more crooks and turns the better; and it seems that the very highest class designers have gone to extremes, the probable reason being the lack of definite data as to just how much deflection a given pipe bend will safely withstand. Definite technical data on this point and as to the reactions necessary to produce the deflection would be welcomed by both designers and manufacturers.

Some designers specify that pipe bends shall be made of extra strong pipe. This is not good design, inasmuch as it is flexibility and not stiffness that is required. The argument that the bending produces a thin wall on the outer side of the bend is true but, nevertheless, there remains sufficient strength to take care of all strains.

OTHER DETAILS

The matter of anchoring the lines depends entirely upon the placing of expansion bends or expansion joints. You may be sure that, unless anchors are properly designed and placed, the entire system of taking care of expansion will fail.

It is considered good practice in fabricating to cut pipes short to an amount equal to half of the expansion. This reduces the strains on both the pipes and the anchors.

The details of anchors are so dependent upon the building details that no general statements can be made concerning them.

The draining of steam lines is very important. The very best steam-traps should be used and the entire system should be as nearly automatic and fool-proof as possible.

Some designers advocate the use of a trap for each drain tap or separator. There are, however, many successful plants operating with one trap for each section of the piping. All traps should be by-passed. There should, of course, be drain taps in all natural pockets and at points where pockets are liable to be formed by the closing of two valves. The drain valves should be placed in accessible positions in order that the operator may be encouraged to use them.

Separators should be placed in the leads to all engines or turbines and even though superheated steam is used it has been found to be good practice to install them.

The supporting of pipe-lines should be accomplished as far as possible by hangers rather than roller supports or pipe stanchions, thus securing better adjustment when expansion takes place. The hangers should be adjustable as to their length. The maximum distances between supports is a variable depending upon conditions, and for which no general rule can be made.

Very little has been said regarding the design of exhaust and water lines. The same general principles apply and if the engineer can properly design his steam lines he should find the others quite simple. Taking care of expansion in these is naturally not as serious as in the steam lines and here the various types of expansion joints may be used. For exhaust and low-pressure water service, the ordinary slip expansion joint will be satisfactory. The use of copper expansion joints for general service is not recommended. This type is suitable only where a very small deflection and a fairly constant temperature are to be expected.

The gate-valve with bottom or back outlet should be considered when designing the exhaust system. The valve is really a combination of a gate-valve and a tee and provides an exhaust outlet to the atmosphere, through the atmospheric exhaust relief valve. The use of this specialty between the turbine and condenser often results in reducing the depth of the basement by from two to three feet.

The two points to keep in mind when designing the boiler blow-off lines are that sufficient flexibility should be provided to take care of the sudden expansion of the line and that two shut-off valves should be provided on each boiler blow-off branch.

There are many other details in power piping design but it is impossible to take them up at this time. There are several books published on the subject but none of them, to the writers' knowledge, treats the subject exhaustively. About two years ago *Power* published a series of articles with illustrations giving the piping details of some of the recent power-plants and it is suggested that designers refer to files of this magazine.

DISCUSSION

Mr. Walter B. Spellmire: *Chairman*:* We have listened to an excellent paper this evening, which touches upon matters of great importance to the power-house man. I agree entirely with the author that, generally speaking, insufficient importance is attached to the matter of piping and valves in power-house design.

The question of higher temperatures and superheat is of increasing importance. The tendency in this direction is very marked in the larger central stations, and total temperatures of 600 to 700 degrees are, I believe, becoming common. This tendency is doubtless due in a measure to the gradual increase in cost of fuel, and possibly one factor in this direction is the high thermal efficiency of the gas-engine, which has in a sense been the competitor of the steam-turbine in power generation. Experiments have been carried on in turbine design where total temperatures have been raised to the luminous temperature of the steam-pipe. This has necessitated carrying the pipe on a continuous concrete support to avoid bending.

Mr. J. C. Hobbs:† If attendance counts for anything, the Duquesne Light Company is well represented with about 25 here to-night.

First, I want to comment very favorably upon the particularly fine paper which has been presented this evening. It is one of the most interesting I have ever had the pleasure of hearing. On account of the limited time, it would have been impossible, of course, for the author to cover every detail, but there are a few which I would like very much to have him cover if he will.

The operating man is concerned primarily with the operation of a valve with respect to tightness, not only in the matter of closing the steam passage, but also in the escape of steam into the atmosphere.

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†Assistant to Superintendent of Power Stations, Duquesne Light Co., Pittsburgh.

Valve-stem packing is a subject on which little is known. It has occurred to me that possibly there is a relation between the kind of material used in valve-stems, and the difficulty encountered in keeping the packing from leaking. To be more specific, does the use of "Monel metal" or phosphor-bronze for valve-stems, in preference to steel, result in decreasing the loss of steam through leaky packings? The other point where the leaking into the atmosphere occurs in piping is at the point where almost no loss ever occurs from an actual hole through piping, although sometimes blow-holes do occur in valves or fittings. As a general rule, however, 99 per cent. of the loss through line leakage occurs around valve-stems and at the flange joints. From an operating standpoint, the welded joint without any packing whatever would seem desirable, because there would be no possible chance of any leak occuring during the blowing out of gaskets, which is so often the case.

It is encouraging to note that modern practice has eliminated many of the large fittings in the main steam headers. It would seem to me that this could be carried still further in a great many cases, so as to increase the length of the lines, and reduce the number of joints to the absolute minimum. The reduction in the number of flange joints may result not only in eliminating the chances of leakage, but also in reducing the amount of external surface and the amount of radiation loss.

In connection with the subject of valves, it is noticed that the author has not mentioned the "Venturi" type of valve, which has been little used in this country but more extensively in European practice. I have not had any personal experience with this type of valve, but understand from some of the users that a drop in pressure does occur with it, and that its use is not considered as satisfactory as was expected.

In connection with the subject of gaskets, it is noted that no mention has been made of the type of gasket which consists of sheet packing reinforced around the outside circumference with copper. In a number of installations which I have had an opportunity to observe, the results from this type have been exceptionally good, no trouble having ever been experienced.

The author's statement that a by-pass should be put on every steam trap is mentioned not because I disagree with it entirely, but in order to call your attention to the fact that the installation of a by-pass introduces a chance for loss on account of leaky by-pass valves; also on account of piping complications with joints, increased radiation surface, valve-stem leakage, etc., so that in some cases it is felt that a trap installation would be justified without being equipped with a by-pass. This applies particularly to superheater installations where ordinarily there is not supposed to be any water.

In connection with the installation mentioned by the author, in which a number of drains were connected to one trap, it should be kept in mind that usually the steam pressures in any system of piping are different at different points of drain connections, and that unless special precautions are taken the usual trap system becomes in reality a secondary steam distribution system; the flow, of course, being from the drain point at the highest pressure through the trap system and out at the point of lowest pressure. This usually results in by-passing the water from the point of highest pressure direct over into the point of lowest pressure where it goes to the apparatus.

Very often steam separators are so designed that a considerable drop in pressure occurs in them, and the drain connection, which is supposed to discharge the water, is in reality used to deliver water taken from other points in the steam-main system. Under certain conditions this action can be prevented; however, it is best not to try to connect two points having more than two pounds difference in pressure, and then only in case a check-valve is placed in the drain from the point of lowest pressure. This check-valve must be located at least five feet lower than the lowest point where any of the drains are taken out of the steam line system.

Mr. B. M. Herr:* With regard to vanstone joints, the speaker said that this joint met all conditions of pressure and temperature. It seems to me, if I recall it correctly, there was trouble experienced with vanstone joints at the Buffalo General

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Electric Company, where they used this joint under 275 pounds pressure and 275 degrees superheat, or approximately 690 degrees total temperature. I would like to ask the speaker if he has any information to give us in regard to this installation.

I have seen a description of the combination of vanstone and welded joints, which satisfactorily handles these high temperatures.

Mr. George J. Stuart: Mr. J. Roy Tanner has had a great deal to do with the compiling of this paper, and some of these points we will ask him to take care of. There are two of them, however, which have come under my own direct experience, particularly at the plant of the Buffalo General Electric Company.

The first gaskets installed at that plant were asbestos compositions of some kind which were tight for only a short time. There were also some copper-jacketed gaskets with an asbestos filler and they were not in very long. The gasket that gave them about two years' service was "Durabla," but trouble is developing a little right now at the Buffalo General Electric Company's plant, due to their low load. I was at the plant about two weeks ago, and they were then carrying 17 000 kilowatts against some 70 000-kilowatt capacity, and they shut down every night, and remained shut down till next morning. This, of course, means the cooling and the heating up of the pipes every day, with more or less condensation. They were at that time having a lot of gasket trouble, and were replacing some gaskets with a steel-jacketed, asbestos-filled type. They have some corrugated steel gaskets that have been in there since the starting of the plant, without giving any trouble whatever and judging from our own experience with superheated steam, the corrugated steel gasket is one of the very best gaskets that can be used.

As to the vanstone joints at the plant of the Buffalo General Electric Company, if they have had any trouble from these joints it is news to me. I have made three inspection trips there, going only to look around, and in those three trips I have heard of no trouble with vanstone joints. When that plant was designed by some Eastern engineers, they contemplated using the vanstone joint welded around the rims, but they abandoned that idea, and I don't think they have any good reason to be sorry for so doing.

Mr. J. Roy Tanner: In regard to the vanstone joints, it seems to me that anybody who knows the difficulty of taking down that joint to replace a gasket, will understand the conditions. Even in this carefully designed, up-to-the-minute plant there was some trouble with these gaskets; and had these vanstone welded joints been used, as contemplated, they would have had to be cracked apart to replace joints.

Regarding the packing of valves, I don't know that I understand the inquiry correctly? Do you mean, in the way of corrosion, Mr. Hobbs?

Mr. J. C. Hobbs: Yes.

Mr. J. Roy Tanner: Now, of course, the manufacturer is somewhat handicapped in advising the operating man on that score, because the manufacturer makes his material and sends it out, and if it is satisfactory he never hears of it. and sometimes if it is not satisfactory he never hears of it, because there is enough ingenuity displayed by the operating man to fix it up. Consequently, we are not in as good a position as you are, perhaps, to tell what that corrosion would be in long service. But, to our knowledge, gained from the valves which have come back to our shops for repairs, there has never been any great degree of corrosion around the stems.

However, there should be, at any plant which operates valves, just as careful and thorough inspection of the valves, to keep them in good condition, as the inspections of the piston rods of your pumps or the rotors of your turbines. I recall once that Mr. Stuart and I were called out on some valve trouble, where, if they had been called upon to operate the valves, I doubt if they could have done it inside of an hour, because the threads of the stems were filled with dirt, and probably had never been looked at since they were installed. If you will look after your valves, no matter what the material is, I believe you can keep them from pitting.

Mr. J. C. Hobbs: I agree with the author in the matter of giving attention to the valves, but as a matter of information

would ask what the operators can do in order to take care of the valve-stems so as to prevent steam leakage. Would you recommend buying "Monel metal" stems?

Mr. J. Roy Tanner: If I were building a plant and paying for it myself, I would buy them.

Mr. J. C. Hobbs: That is a very good answer.

Mr. J. Roy Tanner: When you put money into an item that is as expensive as a cast-steel "Monel" mounted valve, the advantage of adding other material in that stuffing box which will be non-corrosive is worth everything that it costs. The additional cost would be a small item, in case your other material should fail—and it would be liable to fail.

You called attention to the "Venturi" valve. This valve has been used occasionally, but it seems to me if the "Venturi" valve were really as good as claimed, and if all the points brought out in its favor were true, it would have come into a good deal wider use than it has. Theoretically, it is a good valve, but its use is quite limited. Of course, any speeding up means some slight loss of pressure—you can't help that; but all things considered, it seems to me that our American practice of using a line of even diameter right through, is not bad.

I think that in the matter of traps, the paper might have been made a little more explicit, because it stands to reason that drops taken from any points in the system where there is a differential pressure, would be liable to back up into the low-pressure side. That should be considered, because, of course, if you should connect up a point in the header with a point in the separator, you would be sure to get a back-up into your separator on the low-pressure side. That would mean that the drips of a group of headers could be very easily taken in, and the separators, as a general thing, could be pretty well kept to themselves.

Mr. J. C. Hobbs: Some piping, which has been in service 10 or 15 years, has been found to have a crystalline structure. It would be appreciated if Mr. Tanner would tell us whether this

is to be attributed to faulty manufacture of the pipe, or to crystallization due to service.

Commenting further on non-return valves, the size of the non-return valve must be made smaller where the steam is delivered to reciprocating engines than where it is delivered to turbines. On a turbine installation it is almost impossible to get the valve too large as far as trouble with the valve is concerned, but with a reciprocating engine installation the valves must be made small enough to insure their rising clear of the seat in order to prevent pounding.

MR. J. ROY TANNER: With regard to the crystalline structure of pipes, that is something we do encounter in the fabrication of vanstone joints. I believe this is due to some process in the manufacture of pipe. It is not annealed after it is welded —after it goes onto the cooling bed and the ends are sheared off. In the matter of pipe fabricating, we have not gone into heat treating to any extent, but we have found as a general thing that crystallization will show up in the fabrication of the pipe. It is more likely to cause rejection of a pipe in the shop than when it goes out in the field, because of the fabricating process, which means cutting the thread with a die or vanstoning, where you have to flare it out pretty nearly at right angles. This means that it will be stressed more, perhaps, in fabrication, than it will afterwards.

The factor of safety in these cases is very high, and the only times where I have known of crystallization giving any trouble were when the fits were not right, and perhaps did not correspond. Now, of course, nobody can ever tell whether the crystallization was there when the pipe was made, or whether it occurred after. It might be either.

MR. WALTER B. SPELLMIRE: *Chairman*: Mr. Tanner has emphasized the importance of the inspection of stationary parts, such as valves, and I feel that the point is well taken. Doubtless he had special reference to valves handling high-pressure steam, but I, in turn, would like to emphasize the importance of inspecting even low-pressure valves.

I know of one serious accident which was narrowly averted in connection with a turbine. The incident occurred where a large gate-valve was used in the exhaust line of a turbo-generator. The valve was a 48-inch gate-valve, motor driven. The engineer opened his throttle valve to start the turbine, but the turbine did not turn over; opening the throttle still further, the turbine still remained stationary, but there was evidence of steam in the turbine. He was a careful operator, and closed the throttle, making a search for the trouble. He examined the motor-driven valve to see whether it might not be shut. On closing and opening the switch on the valve motor, he found that the motor would run normally, apparently opening the valve; but on further examination he found that the valve-stem had pulled out of the gate and that the valve was actually closed.

If this man had not been a good operator he would probably have been killed and the turbine and valve wrecked so completely that no evidence would have remained as to the cause of the trouble. In this respect it would not have been unlike many aeroplane accidents. The casing at the exhaust end of the turbine is built to withstand compression strains and not a bursting strain. With boiler pressure built up in the turbine casing, the unit would unquestionably have been wrecked and many would have thought that the turbine had run away, due to governor failure; whereas the cause of the trouble would have been the pulling of the valve-stem out of the gate-valve of the exhaust line.

Mr. George J. Stuart: I would like to agree with the gentleman regarding non-return valve sizes. The reciprocating engine, especially if it is carrying low loads, will cause a pulsation in the disk of the valves, just enough, perhaps, to raise that valve one-eighth or one-quarter of an inch, but not enough to cause the dash-pot to become effective. A smaller valve will improve conditions. The drop of five pounds in pressure in a turbine installation would seem to be very excessive through a non-return valve, and there must, in that case, be something sticking, or a disk that is very heavy. It might bear inspection.

Mr. J. C. Hobbs: The testing of a number of non-return valves discloses a variety of performance characteristics. To

illustrate, some types act as a dead weight; as with the differential valves in which the disk floats on the steam flow until a certain capacity is reached, after which it acts as a fixed resistance. In other types, the valves seem to open fully at the beginning and create almost no pressure drop at low flows. As the flow increases, the pressure drop to the valve decreases approximately with the square of the velocity.

Mr. George J. Stuart: I would like to ask Mr. Hobbs if he has the data on these cases.

Mr. J. C. Hobbs: Yes, and I shall be glad to give you the details.

Mr. J. Roy Tanner: I want to refer to just one more point: If there were any other part of anybody's plant that represented a cost equal to the valves, I doubt if it would be let go without inspection. They certainly deserve the requisite care and attention to keep them in proper operating condition, because, just as Mr. Spellmire has said, it might otherwise be very disastrous.

Mr. Walter B. Spellmire: Even such matters as the proper packing of valve-stems in certain types of valves is of the utmost importance. This refers particularly to valve-stems which are required to move automatically to shut off the supply of steam to avoid over-speeding or running away of the turbine.

Mr. C. W. Crider:* There was some reference made to back seating of valve-stems so that they could be opened and closed under pressure. I would like to have some information on that.

Mr. George J. Stuart: For years the practice has been to back seat the valves.

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Mr. C. W. Crider: I know that you back seat them, but can you pack them that way?

Mr. George J. Stuart: With some of them, you can, and with some of them, you can't. The workmanship going into the valves in the first place has a great bearing on that question. If they are not counterbored centrally and touched up a little by grinding, they might not stay tight very long. One of the biggest problems in this connection is sediment. If you get sediment, of course the valve will not hold. Perhaps a good many power-houses could not afford to go into the matter of distilling the make-up water, but some have gone into it. Under these conditions I saw a valve when it was opened after two years' service, and the surfaces were absolutely clean. It was "Monel" mounted, and there was no cutting, or anything of that sort.

There is one other way of overcoming the difficulty when repacking, and that is to tap the valve underneath the stuffing-box, and screw in a nipple and valve. The leakage will be carried away, and the repacking greatly facilitated.

Mr. Harry Ottinger:* In a superheated steam system, is it necessary to have separators? What is the idea of having separators if you have superheated steam?

Mr. George J. Stuart: That seems like a good question. But you don't always have superheated steam. You have it, and then you don't have it; and although I don't know that I can explain why, there are times when floods of water are carried right through the line. Have you had that experience, Mr. Hobbs?

Mr. J. C. Hobbs: Yes, but that is a boiler problem, not a piping problem.

Mr. George J. Stuart: I know that some of the manufacturers are requiring a separator in front of the turbines.

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Mr. W. W. Stevenson:* I might mention a case which I happen to know about in connection with crystallization. A six-inch pipe, at least 1500 feet long, was taken down after a good many years of service and, without exception, every length of that pipe was so badly crystallized that it would break off near the flange, and in every case the pipe would break before the flanges would. The old pipe was salvaged and used as posts, and it seemed to me an interesting thing that in almost every case it would break off at the thread instead of the flange. It was a very interesting question whether it crystallized in service, or whether it was due to manufacture. In service it was run through a punching shop where there was a great deal of vibration, and I would judge that it was a clear case of crystallization due to vibration.

Mr. George J. Stuart: Did that pipe have screwed flanges or vanstone flanges?

Mr. W. W. Stevenson: The pipe had screwed flanges.

Mr. H. K. Higgins:† There is one point about the vanstone flanges that I think is not entirely understood. I have run across it even more particularly in other kinds of steel work. There is a class of steel which is sometimes put in pipe and often into other kinds of structures, which contains such impurities that it will crystallize at a certain point back of where it is heated to make flanges or do other heavy work. Heavy rods break off square with almost "glassy" fractures. The trouble is that the heat penetrates from the upset end back to this surface, and for some reason goes no further. It leaves a critical zone of temperature weakness in the material, and when under any particular strain, it breaks. Vanstone joints, of course, can be annealed; if they are annealed, there should be no such trouble with them, but in some cases they don't take the trouble to anneal them.

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Speaking of piping, it has fallen to the lot of some of us older men to work over plants put in before the time of educated designers of piping. It is only within the past few years that piping has been generally considered important enough to require the attention of trained men. The result is that we find some strange things, which, while perhaps not worthy in themselves of being put on record, may be of interest.

For instance, in one plant with which I was at one time connected, there were some heavy reciprocating compound engines, with condensers. The condensers were nearly worn out and it was necessary for us to put in a new exhaust line running down from the engines—quite an extensive horizontal line—then up to the new barometric condenser. There was no room to put the condenser below the exhaust line, which we, of course, would have preferred. This involved some very interesting problems of drainage, and very careful work to avoid the danger of water in the low-pressure cylinders.

Speaking of condensers, I don't know how many have observed that there is such a thing as making your main steam header into a condenser. In one particular job, which I recall working over, there was that exact situation—a very large steam header supplying a very small amount of steam consumption, and, of course, supplied by a large boiler installation, which was necessitated by the big steam headers. Headers can easily be made too large.

Mr. J. Roy Tanner: One important point was brought out by Mr. Higgins: We must not forget that the manufacturer of pipe has been on the job, too. He has had to follow this question, and to follow it very, very carefully. A few years ago, when the fabricator wanted to vanstone a piece of pipe, he didn't go out into the market and buy a piece of pipe. He had to specify exactly what he wanted. I recollect one specification: "basic, open-hearth steel, for vanstoning." I will say now, for the pipe men, that our boys in the pipe shop go right out to the pile and take open-hearth steel or Bessemer steel, and as long as it is good enough to gage, it will vanstone. I think that is a tribute to our manufacturers.

Mr. B. M. Herr: Isn't it true that some engineers require the annealing of vanstoned pipe lengths?

Mr. George J. Stuart: I don't recall having seen a specification of that kind coming into our plant.

Mr. H. K. Higgins: Has anyone seen or used ground vanstone joints without gaskets and welded around the outer edges of flanges? The speaker has seen one plant so built, but has not kept track of it. Does anyone here know how that construction actually works out in service.

Mr. J. Roy Tanner: That is the plan that has been referred to as being contemplated for the Buffalo plant.

Mr. H. K. Higgins: Did you put gaskets in there?

Mr. J. Roy Tanner: We did not do the work at the Buffalo plant, but have been more or less interested in it.

A few years ago it was quite a general practice to leave out all gaskets, and use ground joints. A great deal of work, costing many thousands of dollars, was handled in that way, and somehow or other a leak would start through that grinding and sooner or later the ground job would turn into a gasket job.

Mr. B. M. Herr: I am able to tell you of a number of such places. One is the Joliet station of the Illinois Public Service Company, where they are carrying 350 pounds pressure and 200 degrees superheat, or a total of about 635 degrees; another is the plant of the American Gas & Electric Company, at Windsor, W. Va., where they carry 225 pounds pressure and 225 degrees superheat, or a total temperature of about 625 degrees; another is the Suburban Gas & Electric Company, of Cromby, near Philadelphia; another, the Union Gas & Electric Company, at Cincinnati; and another, the Northwest station of the Commonwealth Edison Company, Chicago. In every instance this

joint has given perfect satisfaction, not a bit of work being done on the joint after its original installation, and every joint being bottle tight.

Mr. George J. Stuart: I should like to ask if that joint is ground, as well as welded?

Mr. B. M. Herr: Yes, they are both ground and welded.

Mr. George J. Stuart: I cannot see the use of grinding a surface absolutely true in order to make it steam tight, if you are going to distort it afterwards by the use of a welding torch.

Mr. B. M. Herr: The heat is applied only to the edge of the pipe bell, and probably does not even travel across the face of the belled flange, and therefore is not very apt to cause distortion. I think perhaps the flange would be just as satisfactory if the joints were simply rough machined, because the weld is used as a solder to stop leakage. The bolts are designed to take care of the pressure and are ample to do this even if the whole area within the weld is subject to boiler pressure. The weld itself has only a very small area of pressure upon it, and has ample strength to hold the tips of the pipe bell together, even if there is a slight warping of the supporting flange. It is true, however, that in some cases the practice of grinding these joints has been discontinued and they are simply machined.

Mr. P. A. Young:* Considerable reference has been made to "Monel metal" stems, but nothing has been said about phosphor-bronze. One manufacturer of valves, for high superheat is using phosphor-bronze stems almost exclusively, and a manufacturer of large turbines is also using phosphor-bronze stems with "Monel metal" disk seats for the throttle valves.

The paper also refers to flexible connections between the steam header and the prime mover. Much attention is being given to this subject at the present time, and experience shows that much of the trouble due to misalignment and distention of casing is due wholly to stresses caused by improper piping. The expansion not being taken care of in the piping must necessarily be

*Duquesne Light Co., Pittsburgh.

imposed on the parts to which it is connected and sometimes these have a very thin shell and were never intended to take care of compression strains.

The welded flanges at the Commonwealth Edison Northwest station have, so far as I know, given satisfaction; but in making the joint, they replace the bolts, for those not subjected to the heat due to welding.

Mr. J. Roy Tanner: With proper design, there is no reason why phosphor-bronze stems should not be used, but with a seat in the valve the steel body and the seat do not expand uniformly.

We have found that "Monel metal" is not very good as a bearing metal. Where there is much rubbing of surfaces, other materials are preferable, but for a valve-stem, very little fault can be found with it, in our opinion.

Mr. H. K. Higgins: The writers of this excellent paper have very properly devoted considerable space to drainage of steam-piping. This is a very important item. Water in a steam-pipe is so destructive an agent that even some prolixity might be forgiven. The fact that any possible pocket may be drained should not blind us to the better practice of avoiding pockets, even at the cost of some, thought not too much, inconvenience.

Any pocket in a steam line will fill with water, constituting a menace to whatever engine or machine may be beyond it. Automatic drains sometimes fail; separators or steam-traps have limited capacity; manually operated drains, whether trapped or not, may be forgotten; not all attendants in steam plants celebrate wisely the night before; but a dry main never forgets nor fails.

A downtake to an engine must, of course, be drained. There is no help for it. A riser from a boiler to a main can always have its valves at the high point and so avoid the need for drainage. This may involve a sacrifice of accessibility, but may usually be remedied by a chain-wheel on the valve or, better still, a motor if the valve is large.

The extra joint and the occasional inaccessibility are a low price to pay for the added insurance against accident inherent in the elimination of even one possible water pocket.

NOTES ON BRONZE AND BABBITT BEARINGS

By W. K. Frank*

The variation in type of bearings is so diversified and the character of requirements so different with every kind of mechanical device, that were an attempt made to cover the subject completely, the work would require many volumes instead of the few pages of the present paper. These notes are, therefore, restricted to a discussion of bronze and babbitt bearings. An endeavor is made to cover briefly such information as will be of value to the average engineer, and for this reason only such metallurgical data as are essential to an understanding of structural limitations have been included.

A bearing may be defined as that member of a mechanical device which constrains a moving part in its travel. The most common type is the axle or journal bearing used in all machines having rotating journals. It may completely surround the journal or may cover only a portion of it. The journal may rotate continuously, may rotate intermittently, or may have reversing rotation. The bearing may be subjected to pressure from one direction only, as in electric motors; alternating pressure, as in engine crank-pin bearings; or alternating pressure, combined with reversed rotation of the shaft, as in engine wrist-pin bearings.

Two other common types are thrust-bearings and guides. Thrust-bearings are designed to take the pressure created by the end thrust of a shaft, and although in most equipment this function is served by the axle bearing, some conditions such as the thrust exerted by the propeller shaft of a vessel or the pressure exerted by heavy vertical shafts, require special treatment. Guides are surfaces by which the moving part is constrained to a line, and they play a large part in machines having reciprocating parts.

It may be well to show, in passing, the position covered by plain bearings—that is, those of sliding contact—as opposed to

*Vice President, Damascus Bronze Co., Pittsburgh.

ball- or roller-bearings, called bearings of rolling contact. Plain bearings furnish a rugged construction which is subjected to every kind of mistreatment to which a mechanical part is heir, and in the great majority of cases they do their work satisfactorily. They operate under heavy impact, continuing perhaps a thousand times a minute and 24 hours a day; in acid fumes; sometimes with scanty lubrication; under dirt and mill scale or at an intense heat; often improperly aligned and momentarily required to reseat the shaft. Rolling bearings are admirably fitted for certain classes of service, but the necessity of the balls or rollers being made and maintained in a condition of extreme accuracy, measured in ten-thousandths of an inch, makes them impractical under the heat at which a rolling-mill bearing or wrist-pin bearing operates. The inherent limitations of design of the rolling type prevent any considerable adjustment to compensate for the wear, which does occur, and the replacement of this product of the highest mechanical skill requires an expenditure which is not inconsiderable.

The reduction in friction, and consequent saving in power, effected by rolling bearings is a potent argument in their favor, and were it not for the limitations of application for the reasons given, this type would have found much more general application. It will, therefore, be seen that plain bearings serve a particular field and that they are called upon to render service under trying conditions.

Friction is the name given to the force which opposes motion, and is, therefore, ever present between the journal and the bearing. It is found in all manner of mechanical devices and, strangely enough, is one of our most valuable and at the same time most destructive forces. Without friction, brakes would lose their value and nuts would never be used on bolts. Trains would of necessity run on tracks provided with gear teeth and we could not walk as we do now, but would be compelled to find other means of locomotion. Friction, however, is not desirable in bearings. Although much experimental work has been done on this subject, the laws of friction are as yet but little understood.

The surfaces of all materials which appear smooth, are in fact made up of microscopic hills and valleys. When two sur-

faces in contact are moved relatively to each other, the clashing of the points creates a force which opposes motion. Wear results from this action and the energy expended is converted into heat.

Fluids, as well as solids, show friction and this has been described as the force encountered in rolling the particles of the fluid against one another. The laws of friction in fluids and solids are quite different and these have been summarized as follows: For solids, dry or slightly lubricated, frictional resistance is proportional to the load; it is independent of the extent of the rubbing surfaces; except at very low speeds it decreases as the velocity increases.

In liquids, the frictional resistance is independent of the load; is directly dependent on the extent of the rubbing surfaces; and increases as the velocity increases.

The function of the lubricant in bearings is to separate the surfaces by a film so that metallic contact does not occur. If such a separation does take place the friction resulting will follow the laws for fluids. It has been well established by Tower* that under conditions of perfect lubrication the journal is actually fluid borne and in this case the laws of fluid friction may be applied. He showed that when a bearing is plentifully supplied with lubricant the friction depends very little on the load or character of the surfaces but is dependent on the extent of the surfaces, the velocity, and the character of the lubricant. Lubrication of this type is obtained by means of a bath or flood of oil drawn between the surfaces or by a forced feed system. In order to maintain the oil film, however, the bearing pressure must not exceed certain limits. This critical pressure depends on velocity, fit and finish of the surfaces, temperature, and the viscosity of the lubricant. Formulas have been laid down and it appears that a safe maximum pressure is $Mp = 15.53\sqrt[3]{v}$, where maximum pressure is in pounds per square inch of projected area and v is the peripheral speed of the journal in feet per minute.

Tower's experiments were made with the load and bearing above a journal, the lower part of which was immersed in a bath of oil. He found that the journal carried the oil between

*Proc. I. M. E., v. 34, p. 632–659.

the surfaces and formed a film between them. One of the most interesting points of his experiments was noted quite accidentally. In the course of his work he had occasion to drill an oil hole at the top of the bearing and found that the oil flowed freely from it. He attached a pressure-gage at this point and determined that a pressure of over 200 pounds per square inch was developed, although his load was only 100 pounds per square inch of projected area. Later experiments showed that the pressure of the film at the top was greatly in excess of that at the sides and that it was greater on the discharge side than on the entering side. The thickness of the film has been determined as between 0.0013 and 0.0029 inch.

However, in most applications such ideal conditions are not reached and usually on starting we have the surfaces in contact and subject to the laws of friction for solids. Lubrication is often interrupted or imperfect, by reason of improper distribution, and we have friction which does not follow exactly the laws either of solids or of liquids, but is intermediate between them. This is the type of intermediate friction encountered in bearings with which the present paper deals, and it is necessarily an indefinite quantity depending on all of the named variables. It will be seen that the matter of the character and supply of lubricant, as well as the nature of the surfaces, will be important factors in determining the friction and wear of the surfaces.

Since lubrication is so vital in the matter of friction and wear, prime consideration should be given to it in bearing design. Every effort should be made to create a film although it is not always practicable nor desirable to provide bath, flood, or forced lubrication. Various methods for supplying the lubricant are in use. Drop feed lubrication, which is the simplest form, requires only a hole in the bearing through which the oil is introduced. Unfortunately, this hole is often placed at the point of greatest pressure, so that no opportunity is allowed for the establishment of a film. Introduction at the point of minimum pressure would probably reduce both wear and friction.

Saturated pad lubrication is employed in some cases, the most common example of which is the railroad car bearing. The

bearing covers only the upper third of the journal and waste, saturated with oil, is pressed against it from below.

Ring or chain lubrication is used on many line-shaft bearings and on the bearings of electrical equipment. Chains or rings are provided of a diameter considerably larger than the journal and resting on it, and these run in grooves in the bearing and through a reservoir of oil. Rotation of the journal causes the rings to rotate at a slower rate and they then carry the oil with them to the journal. Good results have been obtained by this method, and it is claimed by some authorities that conditions closely approaching perfect lubrication are reached.

Flooded lubrication consists of pumping the oil or carrying it by gravity in large volume to the bearing and delivering it at practically no pressure. Perfect films are often obtained and the added advantage of dissipating the heat of friction brings it into use with large high-duty bearings. Forced lubrication is used in a limited number of cases. Oil is pumped to the points of maximum pressure and a perfect film is maintained. The pressure of delivery at the bearing must therefore be above the pressure of the film, and ranges from 15 pounds per square inch to 600 pounds per square inch.

Grease lubrication is applied principally to heavy, slow-moving machinery. The grease may be forced into the bearing by means of a screw-cap or it may be drawn in from the minimum pressure points, as in rolling-mill operation. Considerable friction is encountered from the lubricant itself, but under heavy pressures the "body" of the grease prevents abrasion by the tenacity with which it clings to the respective surfaces and separates them.

Oil grooves are resorted to in many bearings in an endeavor to secure a film. However, when the film is once formed, the grooves are a distinct hindrance to its maintenance. Grooves should, in general, not lead into the region of maximum pressures, as in this case they may actually lead the oil away from instead of towards the place where it is most needed. Grooves should preferably be placed in the region of minimum pressures and should run parallel to the axis of the shaft. Care should be

taken to round the edges of the grooves to minimize the danger of injuring the film.

In bearings subjected to heavy loads the oil or grease may be entirely squeezed from between the surfaces when motion ceases. Grooves to the pressure points will provide convenient reservoirs of grease for starting and thus prevent abrasion and this is the only case where such grooves should be countenanced. Errors in locating grooves may be avoided, to a great extent, by keeping in mind the desirability of securing films.

Another factor in securing proper lubrication is clearance between the bearing and journal. Where the bearing covers only a portion of the journal, the latter can be made smaller in diameter, thus providing clearance at the minimum pressure sides. This is often further increased by planing away additional metal from these sides. The amount of clearance desirable will vary with the velocity of the journal and the nature of the lubricant but, in general, it can be said that too much clearance will decrease the opportunity for the formation of a film. The error, however, is often made on the other side—that is, too little clearance is provided. It should be remembered that the bearing is often rigidly held so that with a temperature rise, expansion of both bearing and journal tend to decrease the space between them.

Clearance should be provided between bearing and container, whenever possible, to allow free expansion. Without this, expansion of the back of the bearing may cause pinching off of the lubricant at the sides and what are apparently perfectly fitted bearings, when cool, may be in fact very badly fitted when they become warm.

Dissipation of heat from the bearing is a matter which is often overlooked. The heat of friction is usually carried away by radiation, but in some cases cooling is accomplished by currents of air, oil, or water. Rolling-mill practice imposes severe obligations in this respect as there is added to the heat of friction, the heat conducted through the roll neck. Water cooling is often employed, but in some cases this is not practicable and the bearing is called upon to run at high temperatures.

Provision should be made for compensating for bearing wear, which, of necessity, always occurs. In straight solid bush-

ings, no adjustment is possible and new ones must be substituted when wear has gone to the point where clearance becomes too great. If, however, the shaft and bushing are tapered, the clearance may be adjusted by sliding the bushing towards the greater shaft diameter.

Bearings which do not completely surround the journal—such as are found in railway cars and rolling mills—automatically adjust themselves for wear in one direction. It should be noted that "seating" of this type tends to decrease the clearance at the sides and lubrication may become impaired. This undoubtedly accounts for some bearings of this character running hot after they have been in service for some time. Decreasing the arc of contact of such bearings has often remedied the trouble and, while a smaller bearing area is the result, better lubrication is probably secured through the reduced tendency toward "seating."

The usual split bearings may be arranged to allow adjustment for wear by placing shims between the two halves and then boring to size. When wear occurs, removal of the shims allows adjustment in a line at right angles to the parting, but no adjustment is possible in the line of the parting. To overcome this difficulty four-part bearings are sometimes used and clearance may be adjusted in both directions. Adjustments for wear are also made in split bearings by means of wedges and cap screws.

Wherever possible, automatic adjustment for alignment should be provided. Shaft bearings are often flexibly held so as to allow for improper initial alignment or deflections of the shaft. Curved seats are sometimes used, though the usual methods are not automatic but consist of fixing and alignment by means of bolts or wedges.

Determining the proper value for journal length and diameter are prime considerations in bearing design. Bearing pressures should preferably be held within such limits as allow the formation of an oil film, but the upper limits for even momentary loads should of course be lower than the limit of resistance for the bearing material.

Bearing pressure is generally stated in pounds per square inch of projected area and the allowable value for a given bearing material is dependent on speed, lubrication, rate of heat dissi-

pation, etc. Longer journals allow smaller diameters and consequent lower rubbing speeds, but, on the other hand, are subject to greater deflections and hence produce more localized bearing pressures. Journals should be checked for fiber stresses, and these may be the determining factor in proportioning length and diameter. In some equipment, factors other than any of the foregoing may determine bearing design. In locomotives, the width between the driving wheels is necessarily restricted to the gage of the track. Boiler design may require a width which will allow short driving-box bearings and, of necessity, the length and diameter are proportioned by other factors than ideal bearing design. Rolling-mill design offers similar limitations and provides no means of increasing bearing area. Necks must be kept short to prevent breakage and, at the same time, diameters cannot be increased since the neck radius is limited to the radius of the roll, minus the thickness of the bearing and carrier lying next to the adjacent roll.

A great range of bearing pressures and speeds is met with in various designs and this may account for some of the discrepancies found in bearing results. Some extremes, cited by Alford,* are: Turn-table and movable bridge bearings, with 7000 to 9000 pounds per square inch of projected area, with very low speeds; as against generator and motor bearings with 30 to 80 pounds per square inch, with speeds of 400 to 1200 feet per minute. Other pressures are: Locomotive drivers 200; locomotive main crank-pins 1600; car journals 300 to 325. Prof. Trinks has estimated that sheet-mill bearings carry loads of 3600 pounds per square inch, maximum, with averages in the neighborhood of 1000 pounds per square inch. Rubbing speeds are low, between 150 and 180 feet per minute, but extreme heat and poor lubrication make this probably the most destructive service to which bearings are subjected.

Bearing design is sometimes checked up by the product of pressure, in pounds per square inch of projected area, and velocity in feet per minute. Various values have been assigned, ranging from 24 000 to 1 720 000. One manufacturer of heavy machinery

*Bearings and Their Lubrication. 1911. p. 65–68. McGraw-Hill Book Co., N. Y.

limits this value to 60 000 for ordinary lubrication, while 1 100 000 seems to be good practice for locomotive main crank-pins.

The material from which a bearing is made plays a large part in design. While bronzes and babbitts are the principal materials used, cast-iron, wood, fiber, etc., answer for some conditions. Very little wear has been observed from some cast-iron bearings, but it should be noted that good lubrication was provided and the pressures and rubbing speeds were low. The choice between babbitt and bronze will be made from considerations of speed, pressure, and temperature of operation, as will be shown later. Babbitts are softer and have lower melting points than bronzes, and are therefore adapted to conditions of lower pressure and temperature. Bearings subjected to impact should not be made from babbitts, because of the malleability of these alloys. The lower melting points and malleability of babbitts are, however, the properties that make them easy to handle and they are for this reason widely used. Accurate bearings may be secured without expensive machining, or they may be die cast and made into intricate shapes without any machining whatsoever. Their plastic character allows them to conform to the load and prevents localized pressures. Bronzes, on the other hand, have comparatively high melting points and are, therefore, not so easily handled. They are generally furnished by a bronze foundry in the form of castings, whereas babbitts are supplied in ingot form for application directly by the equipment builder and user.

Babbitts are poured into cast-iron, steel, or bronze shells to give them the necessary backing, or may be poured directly into a recess provided in the machine itself. In this latter case, and where the cast-iron or steel shells are used, proper means should be provided for anchoring the babbitt. Dovetails or radially drilled holes are generally sufficient, but peening the babbitt before machining will decrease the chances of its becoming loosened. Bronze backing is supplied where there is a possibility of the babbitt melting or wearing out. In this case the bronze will continue to carry the load without abrasion of the shaft, as would occur were cast-iron or steel backing used.

If a bronze shell is properly machined, a coating of solder properly applied will cause the babbitt to adhere firmly without

the use of dovetails. Railroad car bearings are lined in this manner and if the work is properly done and pure materials are used, no trouble with loose linings will be observed. Some years ago, experiments made by the company with which the writer is connected, showed conclusively that loose linings in car journals were caused mainly by the arsenic contained in antimonial lead generally used for linings. With arsenic below 0.25 per cent. no trouble was experienced and it may be said that such linings properly applied will tear apart before separation from the bronze takes place.

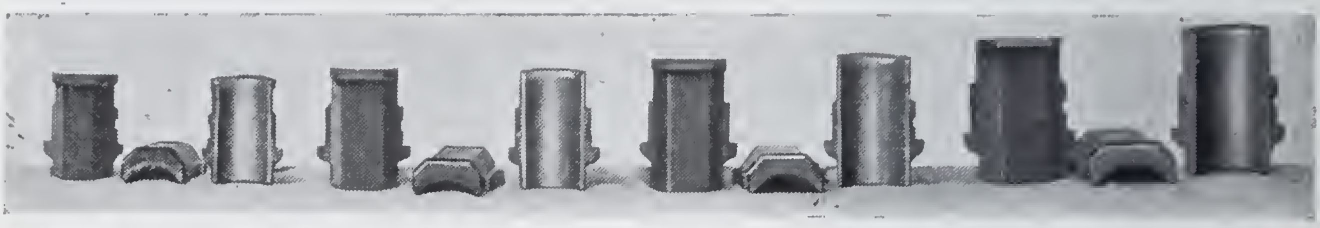

Fig. 1. American M. C. B. Car Bearings.

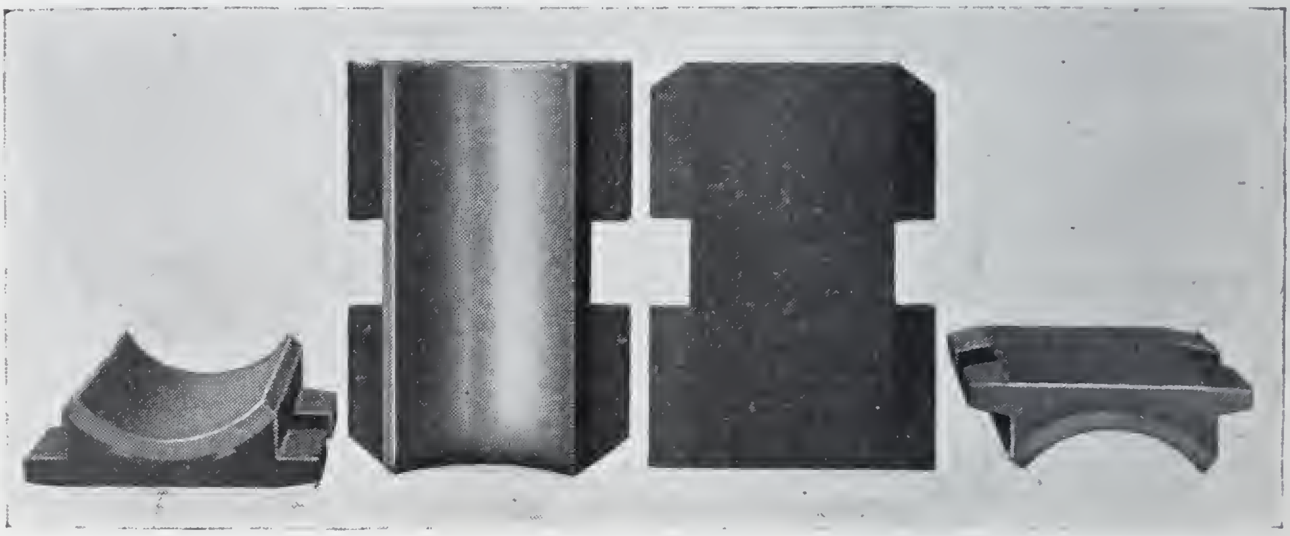

Fig. 2. French State Railways Car Bearings.

Fig. 1 shows babbitted American car bearings, without dovetails; and Fig. 2, French car bearings, with dovetails. In the latter, circumferential recesses are also provided. In view of the large numbers of the American design in use, and the minimum of trouble experienced from properly applied linings, it would appear that the dovetails are not necessary and, in fact, are undesirable. Proper cleaning of the grooves is difficult and heating may be experienced from sand or scale, in the event of the linings being worn through. Bronzes with babbitt pockets

only partially covering the bearing area are common in rolling-mill practice, and these composite bearings have some valuable properties.

A fair question would probably be: "Why use bearings of bronze or babbitt? Why not use steel, or cast-iron, or brass, or aluminum, or something else?" It is fairly accurate to say that similar materials do not work well together. In any given substance, two pieces made under similar conditions will show a similarity in microscopic hills and valleys. Since friction is caused by the interlocking of these hills and valleys in parts passing along one another, and inasmuch as the interlocking will be much more complete between surfaces having similarity of arrangement than between surfaces having dissimilar arrangement, it may be seen that the force required to break the interlocking of similar surfaces will be the greater. This may explain why a journal and bearing of the same material are not used, but it does not tell us why some materials are preferred to others in bearings.

Since the necessary oil film is destroyed by the pressure of the shaft at rest, it is desirable that some method should be had of restoring this film quickly when movement starts. It is, therefore, essential that a supply of oil be close at hand, and a material which of itself provides convenient reservoirs scattered over its entire surface would probably be your selection if you were called upon to design one to meet the condition described. As has been stated, all materials have points and depressions to a greater or less extent, but in the bearing metals after a short period of service we find this condition much more marked than in other materials.

Bearing metals are essentially a mixture, the components of which are distinctly different in hardness. In these metals the softer crystals are abraded faster and develop into depressions, allowing the harder ones to stand above them and support the load. These softer crystals perform another function also. A bearing should be plastic to a limited degree, since fitting is more or less of a rough approximation. Furthermore, a change in

alignment of the shaft will produce points of concentrated pressure and the bearing must be capable of reseating itself to distribute its load properly.

Another bearing requirement is that it shall protect the shaft against injury. Unfortunately, wear is always an attendant evil of motion, and it is preferable that the bearing wear rather than the shaft. In most designs the bearing is the less costly part and is the more easily replaced, hence its harder element should be softer than the shaft. The bearing should also be of such a nature that it will not grip or be capable of welding itself to the shaft in case it becomes heated, as serious damage will be done should this occur.

It will, therefore, be seen that the range of selection for bearing metals has been greatly limited by these considerations. The use of pure metals has been excluded because of our necessity for components with greatly dissimilar wearing properties. We are, therefore, dependent on alloys, and on those alloys of which the harder crystals are softer than the shaft; which are capable of conforming to the load and yet able to carry it without rupture or undue distortion; and which do not tend to weld on heating. Other considerations require that these alloys conduct and radiate the heat of friction readily, that they wear slowly and show small friction and that they be capable of uniform production.

The only alloys we know of which combine the desired properties are the bronzes and babbitts. Babbitts fall into two general classes—namely, the tin-base metals and the lead-base metals. Antimony, copper, and zinc are the principal ingredients with the tin and lead, but sodium, cadmium, calcium, barium, bismuth, nickel, or aluminum are added in some cases.

The tin-base, or so-called "genuine babbitts," are variations of Isaac Babbitt's original formula of 89.3 per cent. tin, 3.6 per cent. copper, 7.1 per cent. antimony, and they vary in the percentages of all of these elements and sometimes contain lead or other metals. In these alloys the tin furnishes a plastic matrix, in which are embedded the harder crystals of the tin-antimony, copper-tin, or copper-antimony compounds.

Fig. 3. Tin-Base Babbitt, Magnified 75 Diameters.
Etched with Five Per Cent. HNO_3.

Fig. 3 shows a tin-base metal. The dark background is the plastic tin matrix, the cubical crystals the tin-antimony compound and the six pointed "snow crystals" the copper-tin compound. In the lead-base alloys, the hard crystal forming elements are principally antimony and tin. The matrix is lead, an alloy of lead and tin, or the lead-antimony-tin eutectic, and the hard crystals are usually the antimony-tin compound.

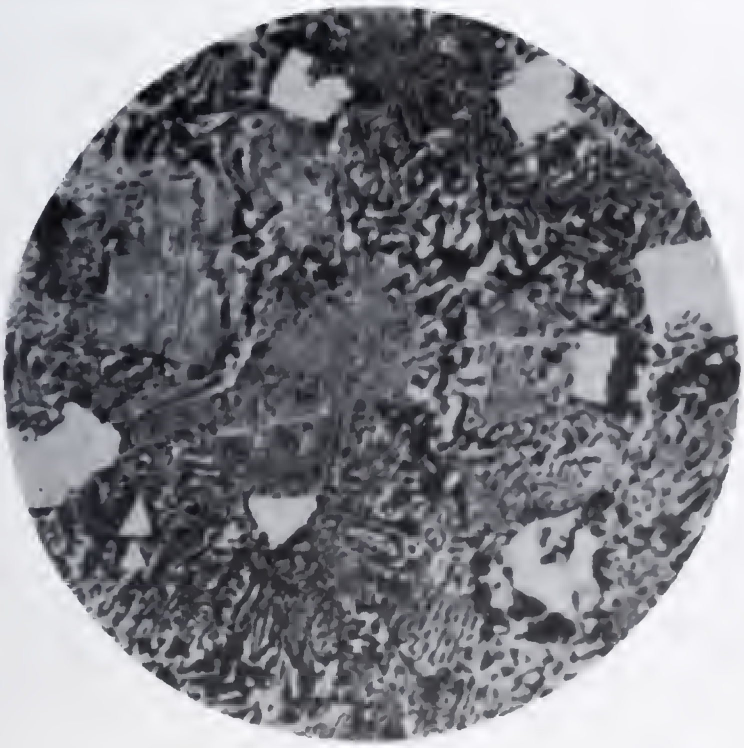

Fig. 4. Lead-Base Babbitt, Magnified 75 Diameters. Unetched.

Fig. 4 shows a typical lead-base structure, with the soft eutectic forming the supporting medium for the hard, cubical, tin-antimony crystals. In the case of lead hardened with sodium, cadmium, etc., these elements probably form compounds with the lead, the compounds constituting the hard crystals embedded in the lead matrix. Lead-base babbitts present a wide range of compositions and are commonly composed of lead, tin, and antimony. With a variation possible in each of these elements, it may easily be seen that almost an infinite number of combinations may be made. The lead is varied between 65 and 90 per cent., the tin between 0 and 40 per cent. and the antimony between 5 and 20 per cent. Varying physical properties are obtained by different formulas, and selection of the proper one is determined by the character of the load, hardness of the journal, lubrication, pressure, and speed.

Babbitts are covered by tentative specification B 23–18 T of the American Society for Testing Materials. The table of physical properties appended to the specification, does not form part of it, but is merely to be taken as information regarding the properties that might be expected from carefully manufactured alloys. It will be seen that the Brinell hardness (all Brinell figures in this paper refer to a 300-kilogram load on a 10-millimeter ball, applied for 30 seconds) varies from 14.3 in the lead-base to 34.4 in the tin-base, and that the deformation with a load of 10 000 pounds varies from 0.007 in the tin-base alloys to 0.285 in the lead-base alloys. These properties indicate why tin-base alloys are preferred for some services, in spite of their higher cost.

It has been pointed out by T. D. Lynch,* as the result of hammer tests by the Westinghouse Electric & Manufacturing Company, that pouring temperatures of babbitts largely influence their resistance to continued impact. The properly prepared tin-base alloys showed little difference in this particular from the properly prepared lead-base alloys, but it was stated that the allowable pouring temperatures of the tin-base babbitts showed a greater range than the temperatures for lead-base babbitts. The

*Study of Bearing Metals and Methods of Testing. Proc. A. S. T. M., 1913, v. 13, p. 699–711.

TABLE I

A. S. T. M. BABBITTS. SPECIFICATION B 23—18 T

Alloy, grade No.	Tin, per cent.	Antimony, per cent.	Lead, per cent.	Copper, per cent.	Iron, max., per cent.	Arsenic, max., per cent.	Zinc, per cent.	Aluminum, per cent.
1	91	4½	0.35*a*	4½	0.08	0.10	none	none
2	89	7½	0.35*a*	3½	0.08	0.10	none	none
3	83⅓	8⅓	0.35*a*	8⅓	0.08	0.10	none	none
4	75	12	10	3	0.08	0.15	none	none
5	65	15	18	2	0.08	0.15	none	none
6	20	15	63½	1½	0.08	0.15	none	none
7	10	15	75	0.50*a*	....	0.20	none	none
8	5	15	80	0.50*a*	....	0.20	none	none
9	5	10	85	0.50*a*	....	0.20	none	none
10	2	15	83	0.50*a*	....	0.20	none	none
11	..	15	85	0.50*a*	....	0.25	none	none
12	..	10	90	0.50*a*	....	0.25	none	none

a Maximum.

TABLE II

A. S. T. M. TABLE SHOWING PHYSICAL PROPERTIES OF WHITE METAL BEARING ALLOYS
(APPENDIX TO SPECIFICATION B 23—18 T)

Alloy No.	Formula.				Deformation of cylinder 1¼ in. diam. by 2½ in. high at 70° F., in.			Brinell hardness.		Melting point.		Complete liquation point.		Specific gravity.	Weight		Proper pouring temperature, deg. F.
	Copper, per cent.	Tin, per cent.	Antimony, per cent.	Lead, per cent.	At 1000 lbs.	At 5000 lbs.	At 10000 lbs.	At 70°F.	At 212°F.	Deg. F.	Deg. C.	Deg. F.	Deg. C.		Oz. per cu. in.	Grams per cu. in.	
1..	4.5	91.0	4.5	....	0.000	0.001	0.015	28.6	12.8	437.0	225	699.8	371	7.34	4.24	120.28	824
2..	3.5	89.0	7.5	....	0.0000	0.0015	0.0120	28.3	12.7	460.4	238	683.6	362	7.39	4.27	121.10	808
3..	8⅓	83⅓	8⅓	....	0.0010	0.0045	0.0070	34.4	15.7	462.2	239	791.6	422	7.46	4.31	122.25	916
4..	3.0	75.0	12.0	10.0	0.0005	0.0025	0.0090	29.6	12.8	365.0	185	555.8	291	7.52	4.35	123.23	680
5..	2.0	65.0	15.0	18.0	0.0010	0.0030	0.0090	29.6	11.8	365.0	185	536.0	280	7.75	4.48	127.00	661
6..	1.5	20.0	15.0	63.5	0.0015	0.0050	0.0180	24.3	11.1	365.0	185	512.6	267	9.33	5.39	152.89	638
7..	...	10.0	15.0	75.0	0.0010	0.0050	0.0230	24.1	11.7	464.0	240	500.0	260	9.73	5.62	159.44	625
8..	...	5.0	15.0	80.0	0.0020	0.0090	0.0620	20.9	10.3	469.4	243	500.0	260	10.04	5.80	164.52	625
9..	...	5.0	10.0	85.0	0.0040	0.0120	0.0840	19.5	8.6	469.4	243	491.0	255	10.24	5.92	167.80	616
10..	...	2.0	15.0	83.0	0.0010	0.0100	0.1540	17.0	8.9	473.2	245	500.0	260	10.07	5.82	165.02	625
11..	...	...	15.0	85.0	0.0010	0.0100	0.1190	17.0	9.9	476.8	247	500.0	260	10.28	5.94	168.46	625
12..	...	...	10.0	90.0	0.0025	0.0170	0.2850	14.3	6.4	476.8	247	509.0	265	10.67	6.17	174.85	634

former are therefore more often properly poured and show better properties.

Lynch's best pouring temperature is 460 degrees C. (860 degrees F.) for both types, while the A. S. T. M. figures are 616 to 638 degrees F. for lead base and 661 to 916 degrees F. for tin base. It may be said, however, that resistance and impact are not the only properties to be considered in babbitt metals, and that the tin-base alloys probably owe much of their popularity to their great fluidity, when molten. Special babbitts, commonly called "white brasses" or "white bronzes," find application in well lubricated service. Their compositions approximate 66 tin, 29 zinc, 5 copper. Their Brinell hardness is high but on account of their more difficult handling they are not widely used.

Babbitts as a class show high plasticity combined with low Brinell hardness and compression strength, and these properties limit their application. Bronzes are, therefore, used where higher physical properties are desired to resist pressure or impact, or to provide longer service. Whereas, in the case of the babbitts, the softer element is the major constituent, so in the bronzes it is the minor constituent. Bearing bronzes are, in general, copper-tin matrices filled with lead. The term bronze applies strictly to a copper-tin mixture as differentiated from brass—a copper-zinc mixture. These terms are frequently loosely used, and it is quite common to speak of bearings as "brasses." On the other hand, manganese bronze, "Tobin" bronze, and a multitude of other so-called bronzes are in reality brasses, to which possibly one or two per cent. tin has been added; and aluminum bronze is usually a mixture of copper and aluminum, sometimes with a small quantity of iron.

The American Society of Mechanical Engineers Committee on Bearing Metals recently pointed out why bronze is preferred to brass in bearings. This has long been understood and the explanation given is undoubtedly the proper one. In the case of a bronze bearing metal of 90 copper, 10 tin, we secure a mixture of at least two dissimilar crystals and possibly three. In the case of copper and zinc, only one set of crystals is formed, up to a high zinc content. A homogeneous mass is formed as contrasted with the non-homogeneous mass of hard and soft ele-

ments in the copper-tin alloy, and the latter mixture is desirable because of the formation of the minute oil reservoirs, as has already been shown. The shop man will tell you that, in a bearing, brass is dry and harsh as compared with bronze, and it is undoubtedly the property of providing oil cells that gives bronze its value as a bearing metal.

Copper-tin mixtures have good hardness and compression strength. An increase is noted with additions of tin up to about 30 per cent., although at about 12 per cent. brittleness begins, owing to the increase in the eutectoid or "bronzite" constituent. Some bearings which require high compressive strength contain more than 12 per cent. tin, but they should be used with caution. One specification for bearings on movable bridges, calls for a compression of less than 1/1000 inch on a one-inch cube under a pressure of 24 000 pounds per square inch, and less than 6/100 inch under 100 000 pounds per square inch. The 90 copper, 10 tin alloy shows Brinell hardness of about 70 and compression of 0.20 on a one-inch cube under 100 000 pounds per square inch.

The majority of copper-tin bearings contain less than 12 per cent. tin and combine hardness with ductility. They are limited to service where alignment is good, as they do not possess sufficient plasticity to conform readily to a shifting load. They find use in some machine-tools and similar equipment, where good alignment may be maintained, and are used abroad on some railroad equipment where speeds and pressures are not excessive and where fitting is carefully performed. With ideal service conditions, a copper-tin bearing will probably outwear bearings containing added metals, but in most classes of service localized pressures caused by changing alignment will produce rapid wear and heating in this composition. Zinc is sometimes added to copper-tin mixtures and the familiar gun-metal is composed of 88 copper, 10 tin, 2 zinc, but the most widely used bearing mixture is the copper-tin-lead bronze.

In bronzes containing lead, we have the reservoir-forming property further enhanced. The lead does not combine with the copper-tin structure, but is only mechanically held by it in the

form of globules. It imparts plasticity to what would otherwise be a more or less rigid structure, in addition to furnishing it with additional oil reservoirs.

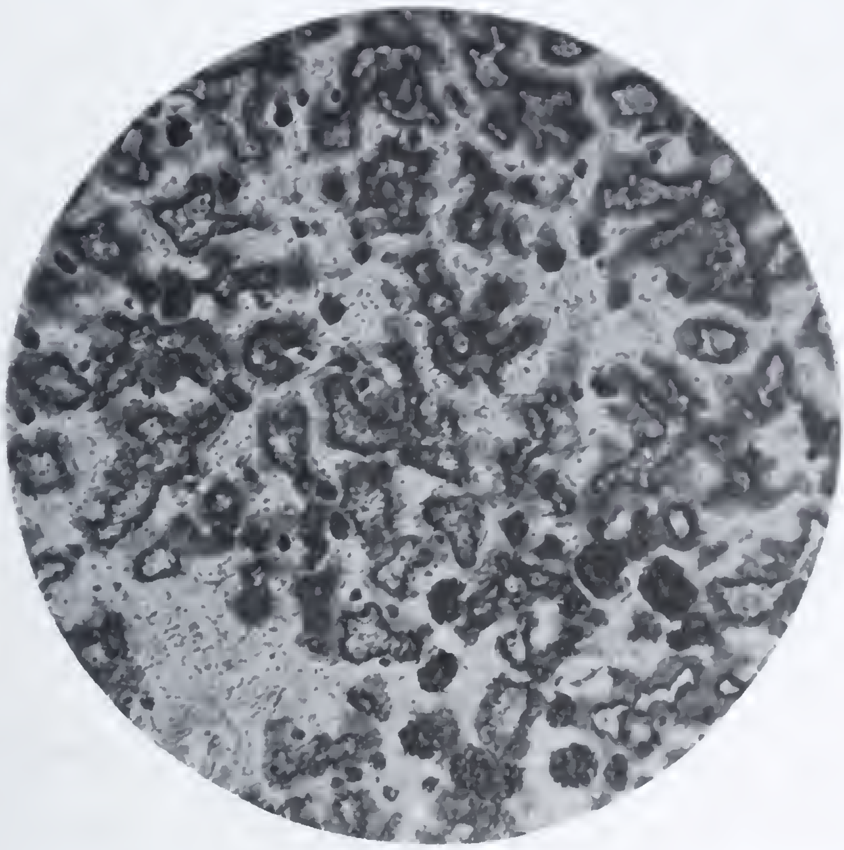

Fig. 5. Copper-Tin-Lead Bronze, Magnified 100 Diameters. Etched with $H_2O_2 + NH_4OH$.

Fig. 5 shows a typical copper-tin-lead bronze. The light colored matrix is the harder copper-tin structure, while the light globules surrounded by dark margins are of similar composition, but richer in copper and softer than the matrix. The black globules are the lead and are still softer. It will therefore be seen that three distinct hardnesses are present. In this mixture we maintain the hard, wear-resisting points of the copper-tin alloy and can vary plasticity by varying the lead content. The lead can be added up to 50 per cent. and this variation gives us the different properties required by varying classes of service. In some cases a very small quantity of lead is added. It produces hot shortness and is therefore not desirable in hot-mill bearings. These may run at very high temperatures, and bearings containing much lead will break under the pressures encountered. A typical low-lead formula of this type would be 91 copper, 8 tin, 1 lead.

At the other end of the scale are found the high-lead mixtures containing up to 30 per cent. lead. They find limited application because of their high plasticity and consequent distortion. They answer well the requirement of protecting the shaft, but do not, on the other hand, transmit heat readily. They show rapid wear, as is evident to anyone who has examined a pile of scrapped railroad car bearings. The high-lead bearings can be readily distinguished from the moderately leaded ones by the extent to which the axle collar has worn into the ends of bearings of the two classes. High-lead mixtures were originally designed to replace the babbitt-lined railroad car bearings, but do not possess sufficient plasticity to accomplish this and are used with babbitt linings. Because of this lining they seldom come in contact with any part of the journal, excepting the collar, and their length of service is determined by the life of the lining, distortion of the back, and collar wear.

It is, moreover, true that high-lead mixtures are difficult of uniform production. Since the lead is but mechanically mixed with the copper-tin alloy, and as lead has a much higher specific gravity, segregation to a greater or less degree is liable to occur in the crucible and mold. As stated by R. R. Clarke* lighter castings which cool quickly can be made with some degree of success, but lead segregation of heavy castings is an accepted evil. Auxiliary agents including nickel, ferro-manganese, and sulphur are used as preventives of segregation, but these are not reliable expedients. Referring again to the scrap pile—the testing laboratory of experience—bad segregations in fractures of a large number of high-lead bearings are revealed. While it is not stated that castings cannot be produced without segregation, it is true that this mixture is easily mishandled and bad bearings result. Unfortunately, low initial cost has recommended it to some users. Conservation of tin during the war led the United States Railroad Administration to specify high-lead bearings for the new cars purchased. The bearing manufacturers will benefit by the replacement that will inevitably be required. A typical mixture consists of 65 copper, 5 tin, 30 lead.

*Casting Bearings in Sand and Metal Moulds. Jnl. Am. Inst. of Metals, 1917, v. 11, p. 167–180.

As in many matters, the best lies between the extremes, and in this case the moderately leaded bronzes best answer most bearing requirements. They can be produced uniformly and well, as no great difficulty is experienced from segregation of the lead. Alloys of this class range from 5 to 15 per cent. lead, and 12 to 7 per cent. tin, with the remainder copper. Copper, tin, and lead all tend to form oxids readily, and deoxidizers are often added. Phosphorus is the most effective of these, and is usually added in quantities in excess of that required for deoxidization and produces an additional hard constituent in the bronze. Phosphor-bronze, as the resulting alloy is called, is one of the most valuable of alloys in present day use, for a great variety of requirements. It presents a comparatively hard surface, and yet is sufficiently plastic to conform to moderate changes in alignment. It answers all the essentials of a good bearing, for moderately good conditions of service. The standard formula calls for 79.7 copper, 9.5 lead, 10 tin, 0.8 phosphorus, and should specify less than ½ per cent. impurities, as too often scrap metals are compounded to produce this alloy and the resulting trouble is charged to the formula, rather than to the impurities contained. For varying degrees of hardness the lead and tin may be varied between certain well defined limits. The standard formula shows Brinell hardness 60, and compression of 0.25 on a one-inch cube under 100 000 pounds per square inch.

As far back as 1892, Dr. Dudley of the Pennsylvania Railroad, determined the practical limitation of lead content for car bearings, to be in the neighborhood of 15 per cent. Later work on this subject has not altered the conclusions he reached in this respect and it may be of interest to note that 27 years later a table of railroad specifications shows the net average content of 15 per cent. lead, and 8 per cent. tin. Dr. Dudley's experiments were real service tests. They consisted of placing on one end of the car axle the standard phosphor-bronze and on the other end the alloy to be tested. He tried a great variety of alloys and of these the only one that showed smaller wear was the one marketed by the company with which the writer is connected. This showed a lead content of 12½ per cent. and tin content of 10½ per cent., and wore 8 per cent. more slowly than the standard

phosphor-bronze. Acting on the basis of a higher lead content producing slower wear, he increased his lead to 15 per cent. and, to reduce segregation, brought his tin to 8 per cent. He found that this alloy was superior to the 12½ per cent. lead alloy and wore 13 per cent. more slowly than the standard phosphor-bronze. He established the 15 per cent. value for lead as a practical limit and, as has been stated, present day practice bears out this figure. It should be remembered, however, that while the 12½ per cent. lead and 15 per cent. lead alloys wore more slowly than phosphor-bronze in railroad car bearings, this is not conclusive proof that the lead is in itself a wear-retarding element. Lead furnishes the means of allowing the bronze to conform more readily to varying alignment and, by preventing localized pressures, reduces wear. Under the comparatively low pressures and absence of impact, but with the changing alignment of car axles, the 15 per cent. lead alloy shows superiority; whereas, under high pressures and impact the phosphor-bronze shows slower wear. It is necessary only to compare the pressures of car axles of 325 pounds per square inch of projected area, with pressures of 3500 pounds per square inch of projected area, encountered in rolling-mill practice, to demonstrate why 15 per cent. lead alloys are not suitable for the latter condition.

It may be said that the formula which will show the least wear under a given condition is the one possessing the greatest hardness compatible with the required plasticity for that condition; qualified, of course, by considerations of sufficient rigidity, lubrication, etc. Unfortunately, we have as yet no manner of predetermining what the limits of plasticity should be for a given condition, so that the proper value of lead must be determined by experience with that service. There is, therefore, no one "best" formula, greatly to the regret of all concerned.

A multitude of mixtures has been suggested and tried. Among the elements sometimes used and in addition to copper, tin, and lead, may be mentioned phosphorus, zinc, antimony, sulphur, nickel, arsenic, silicon, tungsten, vanadium, titanium, manganese, aluminum, magnesium, calcium, and boron. In some cases the added elements are used for purposes of deoxidization, while others are added to obtain increased hardness, or otherwise

altered structure. No extended discussion can be made of the claims advanced for the use of these elements, except that of these, phosphorus is the most widely used and probably owes its merit to its ability to deoxidize the copper, tin, and lead, thus preventing structural weakness.

As will be seen from some of the precautions in design, the bearing that has the best lubrication will last longest, other things being equal. Grit and dirt will often start scoring and it may be of interest, in passing, to note that this remedy is sometimes used in curing "hot boxes." Bearings are occasionally so tightly fitted that little lubricant can enter between the surfaces. Minute oil grooves may then be secured by introducing a small quantity of powdered emery, which makes circumferential scratches on both the journal and bearing surface. Care should then be used in clearing the emery from the lubricant, as abrasion to a serious extent may be caused. Clean bearings, well lubricated, and kept in alignment should give little trouble when properly designed.

Heavy cuts in machining may seriously injure a bearing bronze. Some years ago trouble was experienced by heating in the driving-wheel bearings in new locomotives of one of the railroads. Our company had furnished the bearings and we were called upon to explain the trouble. Chemical analysis of the bronze was made and found satisfactory. The fracture revealed

Fig. 6. Distorted Bearing Bronze, Magnified 100 Diameters. Unetched.

nothing to the naked eye, but when a section was polished and placed under the miscroscope the condition shown in Fig. 6 was noted at the machined edges; whereas, normal structure as in

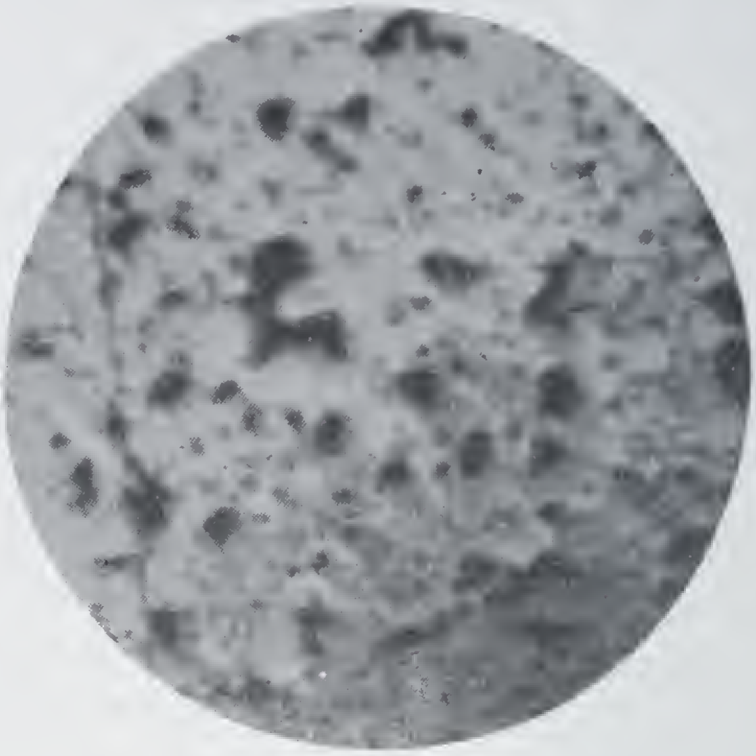

Fig. 7. Normal Bearing Bronze, Magnified 100 Diameters. Unetched.

Fig. 7 was found in the interior points. It was then apparent that heavy cuts in machining had actually forced a large part of the lead from the copper-tin sponge, and a rigid structure was the result. It was suggested that 1/8 inch be machined from the bearing journal surface, to eliminate this distorted metal, and after this was done, no further heating was experienced.

A few of the more common sources of difficulty in rolling-mill bearings are cited below:

Clearance should be allowed for the expansion of the roll in the direction of its axis. Where variations in temperatures are great, considerable friction will be caused by pressure of the roll fillet against the bearings and serious heating and consequent destruction of the latter will occur.

Crossed rolls are another source of trouble by producing high fillet pressures. The rolls tend to move axially in opposite directions and the bearings are called upon to take these thrusts. Often, new bearings are placed in old rolls and the roll neck having a smaller diameter must wear into the bearing quickly to distribute the pressure. On the other hand, where new rolls are

placed in bearings previously used on smaller necks, spreading of the bearing occurs, which may break it through the back, or which, at least, makes lubrication extremely difficult.

Care should be taken with lubricants for all classes of bearings, and the lightest one capable of withstanding the pressure encountered should be used, as needlessly heavy lubricants increase friction.

Too much care cannot be used in keeping out foreign matter. It is not an unusual occurence for roll necks to show grooves two inches deep corresponding to the ridges of iron on the bronze. A small piece of scale usually starts the abrasion and successive layers of iron cut from the neck are deposited on the bearing.

The water used for cooling may be the unsuspected cause of trouble. In this district the river waters at times contain considerable percentages of acids. Heating of bearings under these waters has not been explained, but may be caused by corrosion of the journal or the introduction of sulphur compounds between the surfaces. Electrolysis may occur, as an ideal electric battery is present, and occasional pitting of the bearings lends plausibility to this theory.

Some explanation should be made of the lack of suitable bearing testing machines. It is true that some machines have been designed, but their value lies mainly in the testing of the lubricant. It is practically impossible to duplicate service conditions on the present types of apparatus and, from the foregoing discussion of variations in lubrication and of shifting pressures, this may be understood. With imperfect lubrication, large differences on the same identical test bearing will be noted on different days, and the explanation probably lies in the varying approaches to perfect lubrication obtained.

Tensile and compression tests are sometimes employed to check the uniformity of a given formula, but their extended use is more or less limited by considerations of the expense involved. Analysis is commonly used to check the desired formula, but even this is faulty. The same formula may show large variations in structure caused by different pouring temperatures, or rates of cooling. Structure is obviously the factor which deter-

mines the bearing value and, while a microscope may show the arrangement of the elements, it does not measure hardness or plasticity. The Brinell or other hardness value does not give much information, as pointed out by the Committee of the American Society of Mechanical Engineers. An instrument designed by this Committee, and now being tried, will give a composite value to three of the five fundamental conceptions of hardness—namely, cutting hardness, scratch hardness, and penetration hardness. Such an instrument may prove valuable in checking bearing alloys for uniformity, but its service in initially selecting the proper formula is questionable. As will be seen from the above, little can be expected at present from inspection tests.

As in many other fields, a reliable manufacturer should be consulted for his experience with similar conditions. When suitable alloys are obtained he should be required to maintain uniformity of properties in the alloys subsequently delivered. It should be pointed out that the use of scrap mixtures is a common source of the varying service obtained in bearings and that uniform results can be obtained only from alloys composed of new metals, produced with standardized melting and molding practice. Unfortunately, initial price considerations sometimes rule in the purchase of bearing alloys and the final cost per unit of service is much higher than would be the case with a slightly higher initial outlay.

Fig. 8 shows the common type of furnace used for melting bronzes. The furnaces or pits are entirely below the ground and may be either round or square holes, lined with fire-brick. Coke or coal is sometimes used for fuel, but the furnaces shown are operated with natural gas during the summer and with fuel oil during the winter. The burner is of the combination type and may be controlled with a forked rod inserted through the grating. It enters the pit tangentially and near the bottom and a whirling flame is produced which encloses the crucible and leaves through a flue near the top of the furnace. The crucibles are of the usual graphite and fire-clay type and those illustrated hold a charge of about 600 pounds. They are lifted from the furnace by means of tongs shown at the extreme right of the illustration, the handling being done by an overhead electric traveling crane. The crucible is then conveyed to the molding floor on an overhead trolley system.

Fig. 8. Pit Furnaces Operated with Oil and Gas.

Fig. 9. Tilting Furnaces.

Fig. 9 shows another type of furnace. This employs no crucible and the metal is charged directly into the fire-brick barrels. The burner enters on the end of the furnace, which revolves on trunnions for pouring and the illustration shows a furnace being emptied into a ladle. This is transferred to the trolley system by the overhead traveling crane.

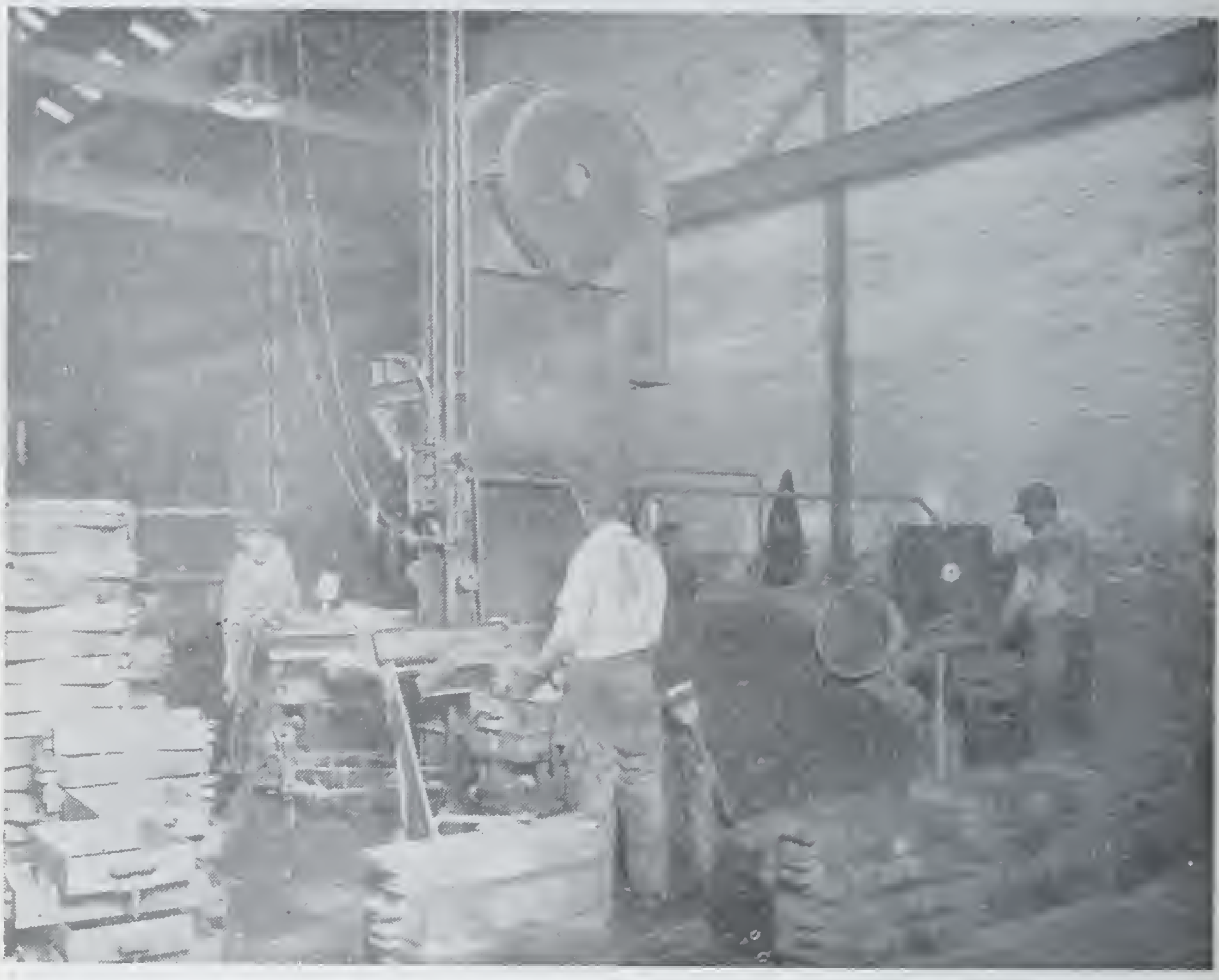

Fig. 10. Molding Machines and Sand Elevator.

In Fig. 10, modern molding machine practice is shown. These machines ram the mold and draw the pattern by means of compressed air. One operator makes the bottom half of the mold, while the other makes the top. The assembled molds are placed behind the operators, below both sides of the overhead trolley track, on which the molten metal is delivered. The molds are shaken over a grating and the sand falls into the sand basement below. New sand is added and a properly tempered mixture is again delivered to the molding floor by the bucket elevator seen in the center of the photograph, each elevator serving four operators.

Fig. 11. Sand-Blast Machine.

The castings are then delivered to the cleaning room, and Fig. 11 shows the revolving table sand-blast machine. The adhering sand and cores are blown from the castings and they are

Fig. 12. Chipping Plate-Mill Bearings.

Fig. 13. Common Types of Rolling-Mill and Railroad Bearings.

now sent to a power shear which removes the gates. Chipping and grinding remove the fins and other irregularities. Fig. 12 shows pneumatic chipping of a plate-mill bearing, and Fig. 13 shows a group of rolling-mill and locomotive bearings ready for shipment.

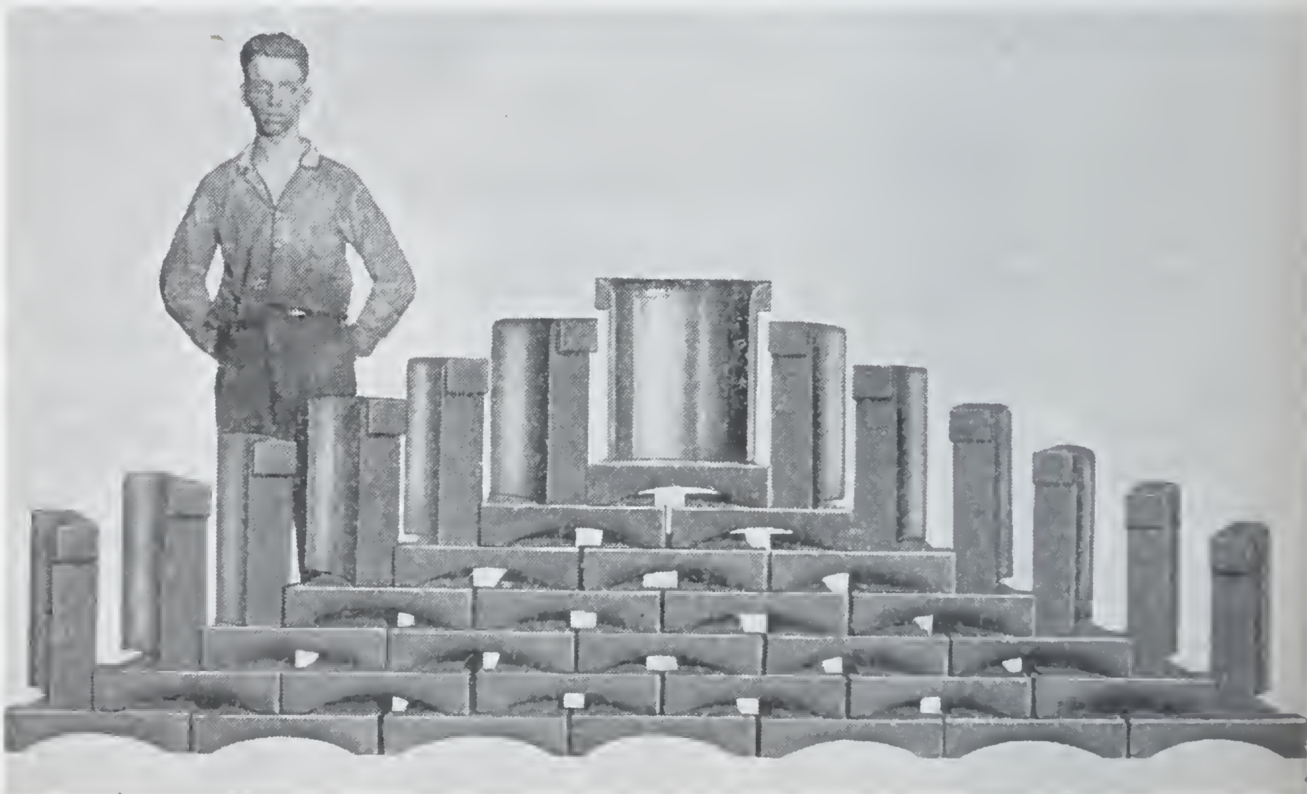

Fig. 14. Machined Hot-Mill Bearings.

Some customers desire machined bearings, as shown in Fig. 14, and such castings together with car bearings are diverted to the machine-shop. Car bearings are bored in special tools, which finish four castings at one operation, highly developed chucking having been made possible by the large quantity of duplicate pieces. Water-cooled, quick-clamping mandrils are employed in babbitting these bearings and the whole operation indicates what may be done, in the way of uniform production and low costs, when a standardized product is being manufactured.

DISCUSSION

Mr. M. P. Clarke:* I would like to ask Mr. Frank if he deems it good practice to groove the bearings longitudinally, whether or not that may destroy the film of oil he speaks about. My experience along this line is that slight clearance with no longitudinal grooves gives the best results. The longitudinal grooves tend to wipe out the film of oil between journal and bearing. If the diameter of the bearing is slightly greater than the diameter of the journal working in the bearing, oil will tend to be carried around under the center of the journal where (in this case) the pressure is greatest. Another value of having the diameter of the bearing slightly greater than the diameter of the journal, is that material never gets a chance to interlock even when stationary, except along the line at the bottom of the bearing.

Mr. W. K. Frank: Oil grooves should be avoided wherever it is possible to introduce the lubricant by other means. They undoubtedly tend to wipe off the film after it has formed, but are a necessary evil in some cases, as without them abrasion would occur on starting. Longitudinal grooves in the minimum pressure areas are preferred to spiral grooves, because they afford better distribution of the lubricant and offer less chance of injury to the film.

Mr. H. A. S. Howarth:† Mr. Frank has covered the subject so very accurately and thoroughly that little comment is needed unless it brings out certain features in more detail. He says there is no good bearing-metal testing machine, and intimates that such machines as are offered for that purpose could better be used for testing oils. It is not clear to me why they are suitable for testing oils.

Professor Thurston years ago designed a machine to test oils and bearings. While Mr. Kingsbury was a student at Cornell, about 1888, Professor Thurston gave him two bronze bear-

*Engineer, National Tube Co., Pittsburgh.

†Associate, Albert Kingsbury, Engineer, Pittsburgh.

ings of different compositions to test. Previous tests by other men had shown one to be noticeably better than the other. As Mr. Kingsbury had considerable practical experience with bearings, he started out by fitting both of them to the journal of the testing machine very carefully. Then he made his tests.

He found there was no appreciable difference between the friction coefficients for the two bronzes. He reported the matter to Professor Thurston who then suggested that a lighter oil be tried. That was done but no difference appeared. He was then advised to try coal oil, which has a very low viscosity. Even with coal oil, Mr. Kingsbury found no appreciable difference between the friction coefficients for the two bronzes. The result of the tests may be explained by the facts that the bronze surfaces had been fitted equally well to the testing machine journal and that they did not extend far enough around the journal to prevent the formation of perfect oil films. Consequently, Mr. Kingsbury was in reality trying to find differences in the oil under the action of two bronzes.

If Professor Thurston's machine be used for testing oils, it does not appear that any useful results can be expected. Oils have many characteristics. The particular property that influences fluid friction is called viscosity. Reynolds, in his mathematical discussion of Tower's experiments, expressed the viscosity of an oil as the ratio between the shearing force within the fluid parallel to the direction of motion, and another ratio made up of the relative velocity divided by the film thickness. If one plain surface moves substantially parallel to another, as in a bearing, the frictional resistance to motion may be expressed as f dynes per square centimeter. If the film thickness is a centimeters and the relative velocity of the surfaces U centimeters per second, the absolute coefficient of viscosity, μ, will equal f divided by U over a. Absolute viscosity is, therefore, the ratio of the friction force to the rate of distortion, $\mu = \dfrac{f}{U/a}$.

It has been suggested by Deeley and Parr that the unit of absolute viscosity be named "poise" after the French physicist Poiseuille who first expressed it in the above form.

The usual method employed in this country for comparing the frictional properties of oils is by means of Saybolt viscosities in seconds at a given temperature, usually 100 degrees F. When it is said that oil has a viscosity of 140 seconds Saybolt, it is to be understood that a standard quantity will flow down through the short standard tube of a Saybolt viscosimeter in 140 seconds. There is a definite relation between Saybolt viscosity and absolute viscosity. The absolute viscosity is most easily used in making an estimate of the friction loss in a bearing. A useful table for converting Saybolt, Redwood, and Engler viscosities into absolute units, was published in the *Journal of Industrial and Engineering Chemistry,* 1916, vol. 8, page 434, by P. C. McIlhiney.

It is evident, from the definition of viscosity, that the thinner the oil film, for a given speed, without regard to the load, the greater will be the rate of distortion and consequently the greater will be the friction loss. In a bearing, that by its construction readily enables a good oil film to form, it is very difficult to break down that film. So long as the film persists at a sufficient thickness, the metals will not touch.

The fact just mentioned led Mr. Kingsbury, a number of years ago, to build a small oil-testing machine that was designed to prevent the formation of a good oil film. A small vertical rod, the lower end of which forms the journal, is arranged to be driven by a drill-press. The journal runs in a bearing made up of two opposing halves. An axial groove is cut down through the middle of each bearing face. These grooves set up conditions that oppose the formation of the film. Consequently the bearing faces can be pressed very close to the journal. Means were provided for putting a known load on the bearing and for measuring the friction that resulted. Two or more oil samples, to be compared, were applied alternately. This machine was designed to test oils for the property called "body," that was supposed to make one oil better than another, under conditions where the oil film is imperfect. When compared in this machine at high pressures, one oil would frequently show less friction than another oil although both had the same Saybolt viscosity at 100 degrees F.

It appears from the above facts that to determine whether one oil is better than another it is necessary to go beyond the limits of film lubrication and get down to the point where films are so thin that the high spots on the bearing faces rub against one another.

The Sub-committee on Lubrication, of the Research Committee of the American Society of Mechanical Engineers, of which Mr. Kingsbury is Chairman, is having some tests made to find out what happens to the viscosity of an oil when it is subjected to high pressure. Professor Alan E. Flowers constructed a device for measuring viscosity at high pressures. It has been found that for pressures many times the mean pressure on a bearing, the oil viscosity is several times as great as it is at the mean pressure. It thus appears that when oil comes between two opposing high spots in a bearing it is subjected to enormous pressure; and that, instead of being entirely squeezed out, its viscosity is so greatly increased that it tends to prevent the surfaces from coming into actual metallic contact. This increased viscosity at high pressures may explain the results shown by Mr. Kingsbury's testing machine. The causes of this increased viscosity at high pressures are not yet known.

Mr. W. K. Frank: Mr. Howarth's interesting discussion illustrates very well the fact that the usual types of testing machine tell us very little about the real merits of oils. His point. that the real value of an oil is indicated when the films are so thin that some metallic contact takes place, applies as well to the testing of the bearing metals. In Mr. Kingsbury's tests at Cornell, referred to, different bronze compositions in the presence of perfect oil films, showed no frictional differences. Imperfect lubrication however had previously indicated that one bearing was better than the other. In this case, better lubrication was probably obtained in the one sample by better fitting and this sample may or may not have been the better bearing metal. However, had Mr. Kingsbury attempted to test the perfectly fitted bearings under conditions which prevented the formation of good oil films, he probably would have found that friction and wear

varied with the varying approach to perfect films rather than with the bearing compositions.

I had the opportunity of working with the same machine at Cornell and found that with imperfect lubrication no concordant data could be obtained on bearing compositions, inasmuch as no method of controlling the degree of "imperfection" of the lubrication is provided on this machine.

Dr. John S. Unger:* In discussing Mr. Frank's paper, I want to bring out a few points for your consideration. A common practice is to purchase bearing metal, of either bronze or white metal, by analysis. I believe this is wrong. I think all bearing metals should be purchased on their mechanical and physical properties. Since these properties in the same metal are decidedly influenced by the number of times the metal has been remelted, by the pouring temperature, and the size or volume of the bearing, it is very important to know what can be expected from a bearing poured under the best conditions.

Bronze bearings are prepared at the foundry, where it is assumed the bearings are cast under the most favorable conditions. When worn out, the scrap bronze is rarely remelted by the consumer, but is returned to the maker to be remelted and refined by such practices and additions as will produce a metal equal to new metal. This places the responsibility on the maker, and his problem is to produce bronzes having the best qualities for the purpose intended.

Such being the case, I will confine my remarks to the white or soft metals, sometimes made up, and nearly always poured, by the consumer. There are over 100 different compositions on the market, some differing very slightly from others. They may be divided into four classes: Over 70 per cent. tin (tin base); over 70 per cent. lead (lead base); from 40 to 50 per cent. tin; over 95 per cent. lead.

It is a fact that the temperature at which a soft metal bearing is poured exercises a pronounced influence on the ductility of

*Manager Central Research Bureau, Carnegie Steel Co., Pittsburgh.

the metal. This is readily shown by the tensile strength, compression, hardness, and wearing properties. Rarely are such properties specified, but composition is the governing factor.

Mr. Lynch has shown in his paper that a tin-base and a lead-base metal may have the same properties and may do equally well in a bearing. He recommends that soft metal be poured at about 460 degrees C. My experience has been that if soft metal was poured at too low a temperature, it crumbled under the compression test; when poured at 450 degrees C. it showed good ductility and when poured at a dull red, the test would shear off with an angular break or crack, and burst. This does not check with the temperatures recommended by others who advise pouring some six lead-base metals at 330 degrees C. From such conflicting data, it appears that more investigations must be made to determine what are the best pouring temperatures for the several classes of soft metals.

The large factories or mills have their own babbitt shops with one man in charge to make the metal and pour it under favorable conditions. It is their common practice to carry in stock duplicate bearings which are poured up in advance of the time needed. Where duplicate bearings can not be kept in stock, it is the duty of the babbitt man to supervise the pouring of such bearings in position. This practice places the responsibility on one person, who is able to meet almost every works condition by the use of not more than three grades—a hard, a medium, and a soft metal—without ever hearing a complaint about the performance of the bearing in service. It is from the small shop, where the machinist or millwright is forced to pour his bearings that most of the trouble comes. The workman usually has not had an extensive experience in pouring soft metal; does not have the proper tools, ladles, and pots; has no good portable, simple pyrometer or thermometer, and has never been told just what the proper temperature should be for pouring the metal he is to use. The consequence is that in many cases a metal may be condemned and a more expensive and less susceptible metal will be employed.

Soft bearing metals should be purchased on their resistance to compression, their hardness, and their tensile properties, determined at three temperatures, as follows:

Degrees Fahrenheit	Degrees Centigrade
60	16
212	100
300	149

In addition, the seller should furnish the melting points and the best pouring temperature for each grade he offers. This information will enable the purchaser to make a selection of metal based on such physical qualities as are best adapted to his use. In many cases two metals will be found having almost the same properties.

If the cost be consulted, it will be found that one metal may cost several times as much as another, but, if the cheaper metal is properly poured, the higher priced metal will not have any special properties to justify the extra cost.

MR. T. D. LYNCH:* Reference has been made this evening to a paper presented by me to the American Society for Testing Materials in June 1913.*

In this connection I wish to present two illustrations which show very briefly some of the results of the hammer tests on babbitt metals, as carried on by us and presented in the paper referred to. Fig. 15 shows the curves produced by a drop-hammer of approximately ½ foot-pound on a sample of babbitt one inch in diameter by ¼ inch thick. The number of hammer strokes is shown at the bottom of the plate and the thickness of sample at the edge of the plate. At the end of each curve is shown, photographically, the resultant sample of each test. All samples, 1 to 12 inclusive, were from the same material, properly made and having a lead-base composition.

*Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Sample 1 was poured at 320 degrees C., which is too low a temperature, and the resultant sample shows a granular and brittle appearance.

Sample 2 was poured at 700 degrees C.—quite too high—and gives a soft and granular appearance.

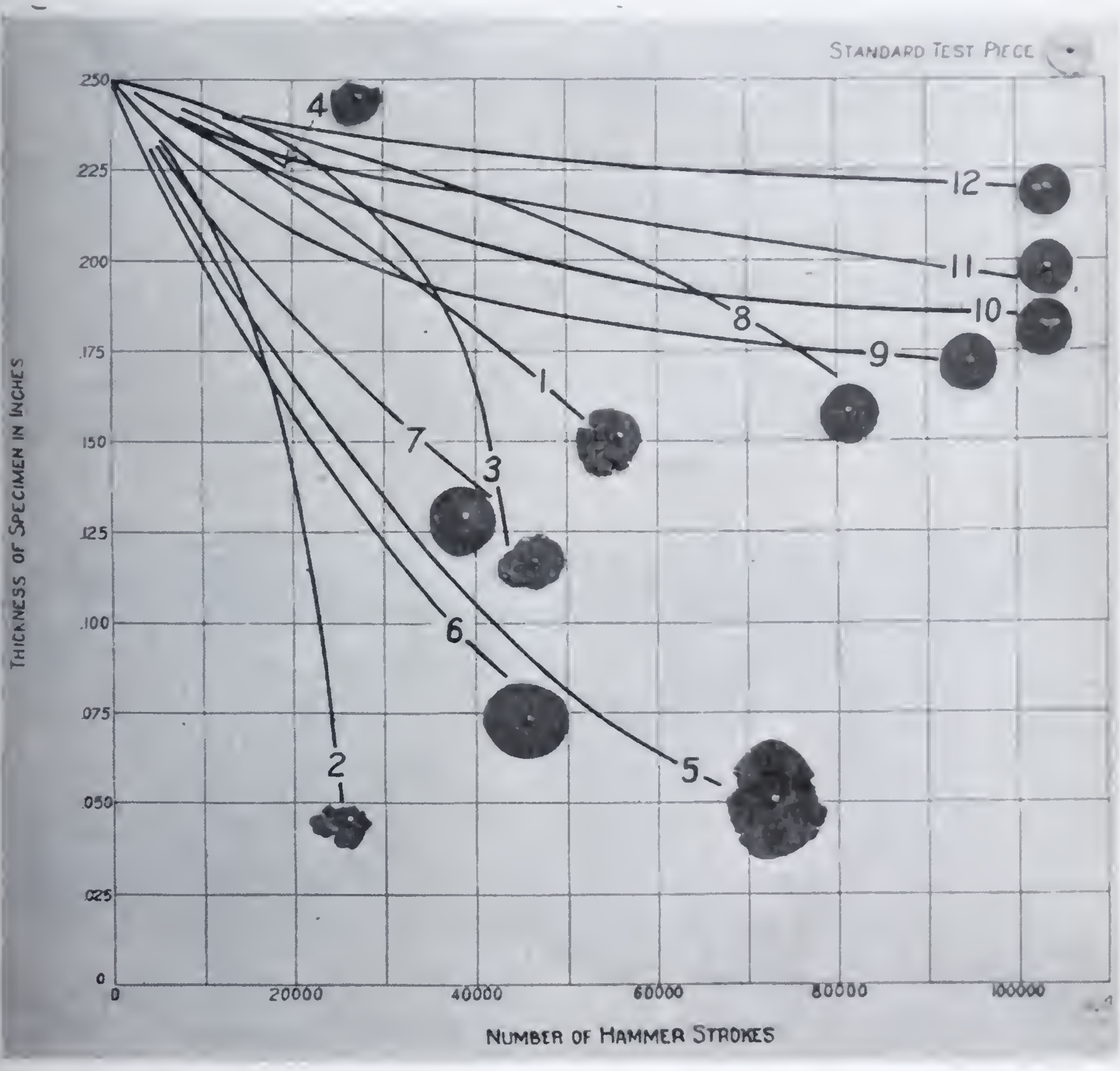

Fig. 15. Drop-Hammer Tests on Bearing Metals, Showing Effects of Manufacturing Temperatures on Babbitts.

Sample 3 was heated several times to 700 degrees C. and cooled, and finally heated to 700 degrees and cooled to 460 degrees, at which temperature the sample was poured. Note the soft and granular structure caused by the overheating.

Sample 4 was repeatedly overheated and finally poured at 650 degrees C. Note the hard and brittle structure.

Sample 5 was heated to 700 degrees C. and cooled to 400 degrees before pouring. This sample was too soft.

Samples 6 and 7 were poured at 360 degrees C.—quite too cold—and the appearance is that of too soft a structure.

Sample 8 was poured at 600 degrees C., having been heated to this temperature very quickly and poured at once. It was tough but slightly soft.

Sample 9 was heated to 600 degrees C. and cooled to 460 degrees before pouring. This was tough and slightly soft.

Sample 10 was poured at 480 degrees C. It was tough and slightly soft.

Sample 11 was poured at 480 degrees C. It was hard and tough.

Sample 12 was poured at 460 degrees C. It was hard and tough.

Curves of the characteristics of 1 to 8 inclusive, are sure to give trouble, while samples having the characteristics of curves

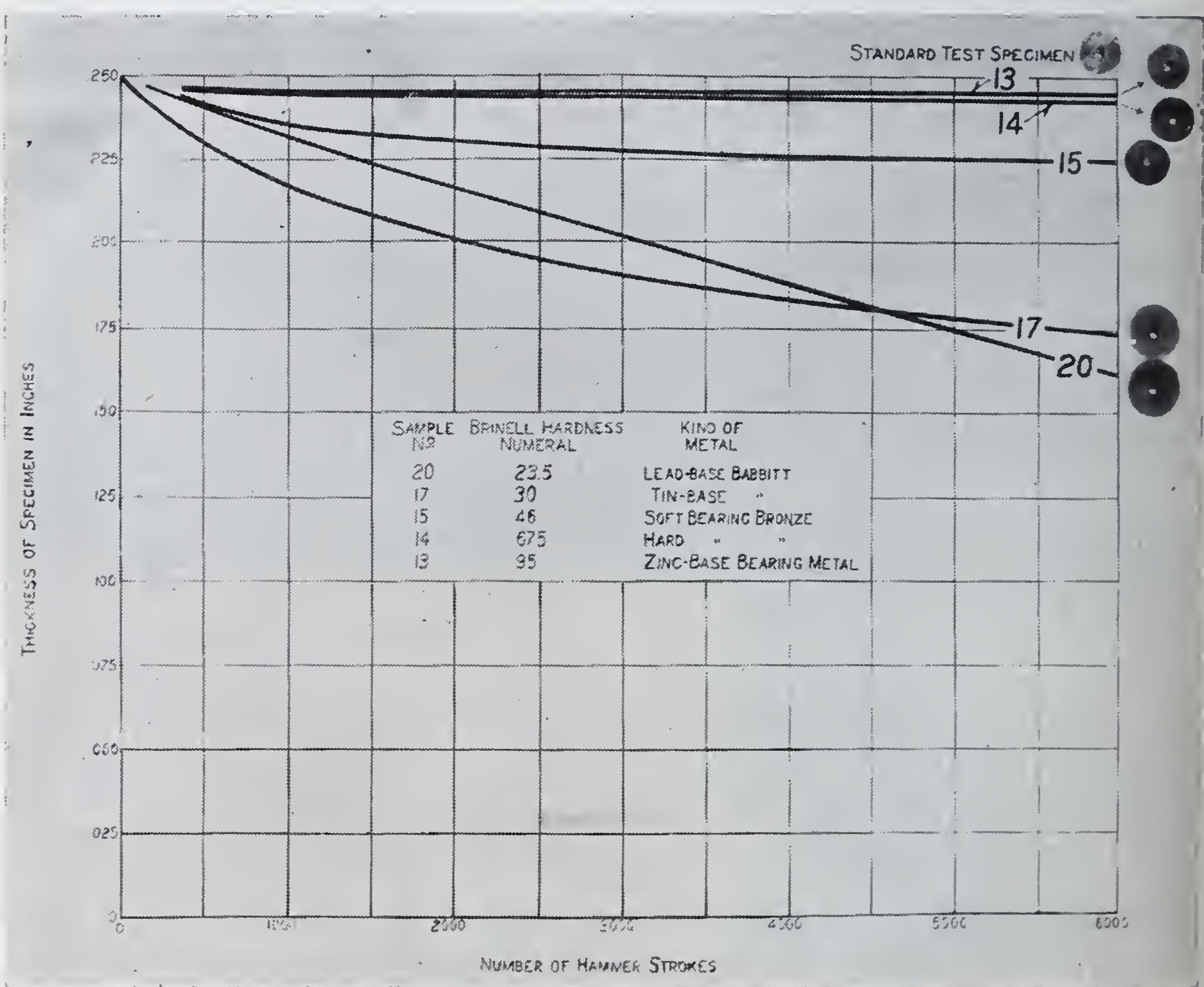

Fig. 16. Drop-Hammer Tests on Bearing Metals. Characteristic Curves of Babbitts and Bronzes.

11 and 12 are always found to give good service as a bearing babbitt.

Fig. 16 is the result of hammer tests made under another hammer having approximately one foot-pound stroke which accounts for the smaller number of strokes to get the final results. The samples, after having been hammered 6000 strokes in each case, are shown at the end of the respective curves.

Curve 13 represents a zinc-base, die-casting, bearing metal; curve 14 represents a hard phosphor-bronze bearing metal; curve 15 represents a soft bronze bearing metal; curve 17 represents a tin-base bearing metal, and curve 20 represents a lead-base bearing metal. These curves are quite characteristic of good bearing metals of the classes represented, and our tests have shown very consistent results with materials used on the basis of these tests. Slight changes have been made in our lead-base metals since curve 20 was made, giving a slightly harder product, our present lead-base metal running approximately 24½ Brinell hardness while the tin-base metal is now running approximately 34½ Brinell hardness. I note from Mr. Frank's remarks that lead-base metal runs as soft as 14.3 Brinell hardness. This hardness numeral of 14.3 would be considered quite too soft for a lead-base metal and we believe that serious trouble would come from the use of such material. The hardness of 27 to 28, however, has been found to give most excellent results.

I would like to state that we have found the Brinell hardness test a most useful one and one that can be used on every kettle of 3000 pounds of babbitt metal made and, knowing the mixture of the material together with this hardness numeral, it is a very safe proposition to use the material having this hardness, other things being equal. This method is being followed by us entirely in connection with the testing of babbitt metals. The sample is made by pouring the metal into a small mold about 2 inches in diameter at the bottom, 2¼ inches at the top and ¾ inch deep. The test is made on the bottom side of this sample and always on the same sized samples so as to get comparative results.

Dr. Unger spoke about 460 degrees C. as the proper pouring temperature given in my paper. I would say that we have found that we can go as high as 480 degrees C. very safely and as low as 450 degrees C. and still get good results. Our practice, however, is to keep as close to 460 degrees C. as it is practicable to do.

In our own plant we have found it necessary to install a regulator on our babbitting pots, so that they will shut the gas off or turn it on when the temperature has changed beyond a predetermined amount, so that we have found it quite practicable to maintain the temperature within approximately three degrees plus or minus the desired temperature—namely 460 degrees C.

Another matter that must not be lost sight of, is that of the temperature of the shells before pouring. We have found it necessary to warm our shells sufficiently to prevent the metal from cooling too quickly when poured into them. The larger the shell the lower the temperature required. The smaller the shell the higher the temperature. If the shell is fairly warm, say 150 degrees C., it helps the metal to flow and we have been able to run the lead-base metal into a shell having a thickness of 1/32 inch, or in some cases, even less.

The question of regulating the temperature in small babbitting pots around a machine-shop has its complications and brings up a very difficult problem for the millwright if it is necessary to pour his babbitt in various parts of the shop. We have found it better practice to have a babbitting place and bring our work to it, which may or may not be practicable for the millwright.

Mr. A. C. Stalknecht:* In the days before pyrometers, the pouring temperature of babbitt was determined by jabbing a stick into the molten metal. Whenever it became quickly and thoroughly charred the metal was ready to pour, the metal first being blanketed with a covering of carbon to exclude oxygen. In some so-called babbitts this occurred at as low a temperature as 450 degrees F.

*Secretary and Chemist, U. S. A. Grease Co., Pittsburgh.

The American Society for Testing Materials Committee on Non-Ferrous Metals and Alloys reported that no babbitt should be poured before reaching 616 degrees F. and the proper temperature where as much as 8 1/3 per cent. copper is incorporated should be at about 916 degrees F.

The proper pouring temperature of the copper bearing alloys is nearly twice that of the melting point, ranging, according to the tentative specifications of the American Society for Testing Materials, from 638 to 916 degrees F., increasing almost directly with the copper content. The so-called genuine babbitt—Isaac Babbitt's pewter—contained about 3 7/10 per cent. copper and its best pouring temperature was about 815 degrees. This had a melting point of about 465 degrees F.

Having so much more at stake and being directly interested in production, the Society of Automotive Engineers has probably done much more intelligent research work in bearing metals than all the other technical societies combined.

The Committee on Lubricants of the American Society for Testing Materials has done a great deal of useful work for the producer, which also has more or less service value. The Society has adopted the Committee's determination as a tentative standard for viscosity. Carpenter says viscosity is a humbug. He is a practical man and producer. The Society has adopted as standard the Committee's tests for cloud, pour, and cold test, and carbon residue, free acid and the method of determining specific gravity. Oxidization, tar, and emulsification tests have not yet been adopted and are of the highest importance to the consumer.

Standardization of lubricants for the consumer's advantage still seems a long way off and it appears should begin with the speed and pressure to which the bearings are subjected and the nature of the bearing metals.

Mr. W. K. Frank: I would like to ask Mr. Lynch to put on record the analysis of the tin-base and lead-base babbitts tested, provided he would not be revealing confidential information.

Mr. T. D. Lynch: The question of chemical analysis of our babbitt metals is one that I would not care to go into at this time.

Mr. W. K. Frank: Mr. G. H. Clamer, Chairman of the American Society for Testing Metals Sub-Committee on White Metal Bearing Alloys, writes as follows:

"I also question the pouring temperatures given in the last column of the table appended to the A. S. T. M. tentative specifications on babbitt metals. The figures given are equivalent to 125 degrees F. above the temperature of complete liquation. I am thoroughly familiar with the figures given by Mr. Lynch in his A. S. T. M. paper of 1913. By referring to the A. S. T. M. table you will note that the figure given by Mr. Lynch is approximately correct for the tin-base babbitt to which he referred. Eight hundred and fifty degrees F. would, however, be too low for No. 3. I seriously question if it is desirable to use a temperature so high for casting the lead-base babbitts.

"It is of course impossible to give a fixed hard and fast temperature as the only correct pouring temperature. A low temperature might be used with better result for casting a heavy section, and such temperature at which the heavy section is cast might be too low to properly flow the metal in a thin section, especially if it has a long distance to run. The temperature of the babbitt when it reaches the far corner of a liner after flowing in a thin section between two relatively cool surfaces would no doubt have a temperature far below the temperature at the point of pouring. In Mr. Lynch's discussion of the subject, he failed to take into account the fact that the metal in being brought to a high temperature absorbs oxygen. I believe it is entirely due to this fact that the babbitt metal is deteriorated, rather than because of structural changes which take place. This is evidenced by the fact that when the metal was first overheated and then cooled down to the pouring temperature; or if overheated and allowed to cool below the pouring temperature and then reheated to a presumably correct pouring temperature, the metal would not then display the maximum physical properties. I believe that the changes in properties which Mr. Lynch attributed to heat treatment are in reality due to chemical change, namely oxidation. It is of course to be supposed that if a metal is cast at a temperature below the complete liquation temperature, that it will be decidedly inferior. I do not believe that there is in existence any really conclusive evidence that bearings of lead-base babbitts if cast at a temperature of 850 degrees F. are superior physically to those cast at the temperatures given in the A. S. T. M. table. The figures as given in the A. S. T. M. table were given as a result of agreement on the part of members of the committee, and as above stated being 125 degrees above the complete liquation temperature are considered safe casting temperatures for the average bearing."

Mr. Joseph Slutzker:* I have listened to Mr. Frank's paper with a great deal of interest. I am with the Pennsylvania Railroad and we consider a good daily operation about 8000 loaded cars, East bound, and approximately the same number West bound. There are about 135 000 bearings running across our division daily. In our passenger service we have probably 50 000 brasses running across our division.

In passenger service we tabulate the number of mechanical failures. If we have three hot journals in a day we consider that bad business. If a passenger who has a 10 o'clock appointment in New York City gets there at 10:45, on account of a hot bearing, the fact that only three out of 100 000 bearings ran hot does not interest nor appease him. With that in view a series of tests was run by the Pennsylvania Railroad with a ball-bearing journal to see how it would compare with brass bearings. The starting resistances of a train with ball-bearings were very much less than the starting resistances of a train of equal weight with brass bearings; but the resistance of the train after getting to a speed of 45 to 50 miles an hour was approximately the same.

We have many trains that start at Pittsburgh and make three stops between Pittsburgh and New York, so in view of that fact and the very powerful locomotives that we have, the starting resistance does not amount to much. The ball-bearings were run a considerable distance, covering almost two years and much difficulty was encountered with the balls. It was decided, therefore, to give up the ball-bearing tests and go back to brasses.

With our very large number of heavy bearings it certainly interests me greatly to know that technical men are giving attention to the proper composition and mechanical structure of bearings.

Mr. Frank spoke of using emery to create an oil groove. When I was an apprentice I fired a locomotive and on one occasion the engineman with whom I was running had a hot main pin. He took a fusee and broke it and poured the contents into the bearing, which cooled down. I never knew why he did it, but thought possibly it was on account of the sulphur. I am now inclined to think it created a groove that assisted the lubrication.

*Master Mechanic, P. R. R., Pittsburgh.

I also recall a series of tests run by the dynamometer car to gain some knowledge of starting resistances in extremely cold weather. Freight trains were taken into the yard along the river, and that is about the coldest place on earth. The train, consisting of 85 or 90 cars, was permitted to lie over night and was started about 4:30 or 5 a. m. A thermo-couple was used to obtain the temperature of the journal on one of the cars. A high temperature was necessary at first to cause the journal to run cool. The sponging in the boxes developed a rather liver-like condition during the night, and it was necessary to run the journal hot to warm that up, and after it was warmed up the journal ran cool.

Mr. W. K. Frank: I am very glad that the discussion this evening has brought out the additional information on pouring temperatures for babbitt metal, as this is a very timely subject. Mr. Slutzker's experiences with ball-bearings are very interesting, and especially the fact that the frictional resistance of trains up to speed was about the same for ball-bearings and plain bearings. I recently heard of an installation of roller-bearings on rolling-mill tables, which proved very satisfactory at first, but which later gave a great deal of trouble, through locking. Expensive replacements were necessary and I understand that the roller-bearings have now been discarded for bronze bearings.

SAFETY AND WELFARE WORK IN INDUSTRIAL PLANTS

By H. A. Schultz*

Attention to the safety and welfare of industrial employees is one of the most progressive movements that has been introduced into the curriculum of modern industrial activities in recent years. Never, perhaps, was a movement more far reaching and intensive. With the full realization of the importance and necessity of such work in our industrial establishments, it has gained such earnest recognition on the part of employers of labor that it may to-day be classified as one of the essential features in successful and efficient plant management. The results which have been obtained since the inauguration of the intensive movement have, in most respects, been very gratifying. Thousands of workers have been saved from serious injury or death. Their health has been preserved through study and correction of processes which in former years have proved injurious. Customs and mode of living have been materially improved and better morale has been established in our industrial forces.

Primarily, the safeguarding of employees against bodily injury in the performance of their duties, and the improvement of conditions which contribute to their happiness and general mode of living, is a humanitarian movement based upon the highest principles imaginable and, from this standpoint alone, it justifies the utmost consideration; but there is also an economic value of equal importance which should not be overlooked. Organized safety and welfare activities in industrial establishments not only insure the employer against injury to the employees, but are productive of increased efficiency and handsome monetary returns.

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The scope of accident prevention activities in industrial plants to-day embodies the following general characteristics:

Thorough organization for the supervision of the work.

Preparation of safety standards and specifications for plant construction and equipment.

Safeguarding of machinery and dangerous areas.

Creation of better and safer working conditions.

Development of a high physical standard and the promotion of good housekeeping.

Elimination of dangerous practices, processes, and conditions.

Provision of proper dress for workmen, which is particularly suited for certain occupations.

Education of workers in safety matters and the inculcation of care and forethought to overcome careless habits.

Development of a hearty co-operative spirit of the employees in the movement.

Training of first aid crews for rescue work and for giving prompt and proper aid to injured employees.

Investigation and study of accidents to eliminate the cause.

Time will not permit a discussion of all of these subjects in detail, but in subsequent paragraphs we shall endeavor to cover generally the more important.

Too much stress cannot be placed upon thoroughness in a safety organization. Where the size of the plant warrants, a competent safety engineer should be employed to supervise the work. Too much, however, should not be expected of the individual serving in this capacity in actually reducing accidents. Safety is not a one man job. When we speak of a safety organization it is not to be interpreted as a few interested individuals who devote a small percentage of their time to the industrial accident problem in a very general way, but a real, live, up-to-

date and enthusiastic organization composed of every individual from the highest official to the rank and file of the workers. Such an organization, working harmoniously and co-operatively together, is the only manner in which may be obtained results commensurate with the fondest hopes.

The movement, from its inception, should have the interest and unqualified support of the management, and its influence should be extended throughout the organization, especially to the operating foremen. From the foreman, much is to be expected in establishing active and progressive accident prevention activities in his department. The foremen should be held morally responsible for the conditions in their respective departments and the safety of the men under them. They should be made to understand strictly that accident prevention is purely a business proposition based upon business principles, and that it should receive equal consideration with production, quality, and cost.

The foreman is the one particular agent who is daily in constant touch with the department and the men. He knows the practices of the department and every phase of the work, and is acquainted with the hazards and knows better than any other individual how they may be overcome. If he gives the proper thought and study to the problem he can do more to educate and influence the men in persuading them to overcome their careless habits and instill that degree of caution in all their movements which will go a long way toward reducing accidents. Men are naturally influenced by their leader, and the foreman, by showing the proper interest, will soon gain the interest of all the men and this, accompanied by the proper discipline, is bound to produce good results.

ESSENTIALS OF A PLANT SAFETY ORGANIZATION

The following outline is based on years of study:

Organization.

1. General or permanent safety committee.
2. Departmental safety committees.
3. Safety engineer (where necessary).

Personnel of General Safety Committee.

1. Chairman (superintendent, or assistant superintendent of plant).
2. Secretary (safety engineer or member of safety committee).
3. Committeemen (three to seven department heads).

Personnel of Departmental Safety Committee.

1. Chairman (shop or departmental head).
2. Secretary (safety engineer or member of committee).
3. Three to five workmen.

Membership of Safety Committees.

1. The general safety committee should be chosen from department heads by the chairman; the safety engineer acting in an advisory capacity to the chairman as to the qualifications of each. The members of the committee should be chosen carefully and should hold office for at least one year.
2. The departmental safety committee should be chosen by the chairman (shop or department head) in consultation with the local safety engineer. The membership of this committee should represent, as far as practicable, the various occupations. The chairman should be permanent, but rotation of membership of the remainder of the committee is recommended, the service covering a maximum period of three months.

DUTIES OF SAFETY COMMITTEES AND SAFETY ENGINEERS

General Safety Committee.

1. To this committee should be submitted for consideration and approval safety matters of importance.
2. Meetings should be held semi-monthly, or oftener if necessary, to pass upon important recommendations made by safety engineers, departmental safety committees, or others, and consider all new safety devices for adoption and standardization.

3. The committee should make frequent inspections of the plant, study practices and render a report, covering recommendations, in the regular manner.

Departmental Safety Committees.

1. It is the chief duty of these committees to establish safer and better working conditions for the employees in their departments.
2. They should make a study of the general conditions, departmental and occupational hazards and practices, and endeavor to encourage the co-operation of their fellow workmen in promptly reporting for correction any existing unsafe conditions or practices through which personal injury may result.
3. These committees should meet at least once a month for the purpose of making formal departmental or inter-departmental inspections. The committees should also review accidents, suggest remedies—physical or operating—and render full reports of meetings, with recommendations to the chairman of the general safety committee.

Plant Safety Engineer.

1. He should have general supervision of all safety work.
2. He should make regular safety inspections of all departments to eliminate accident hazards and dangerous practices.
3. He should expedite the work and see that recommendations are carried out promptly.
4. He should investigate and study accidents for the purpose of making recommendations to remove the cause and prevent recurrence of similar accidents.
5. He should check drawings and co-operate with the construction engineer so that approved standards of design for safety may be incorporated in all new work.
6. He should see that proper safety specifications accompany, or are incorporated in, all specifications or orders for new equipment. (If there are no standard or approved safety specifications for any particular piece of machinery, special specifications should be drawn up.)

7. He should follow up machinery contracted for in outside shops or under construction in the plant to see that all items as called for in safety specifications are included during construction and installed with the equipment.
8. He should supervise and conduct safety educational work.
9. He should prepare appropriate bulletins and see that necessary "danger" signs are posted.
10. He should attend all meetings of safety committees, acting in an advisory capacity and, as secretary of the committee, prepare proper reports.
11. He should attend and participate in all courts of inquiry held to investigate accidents.

The general physical lay-out of an industrial plant or shop, to provide fully for the protection of the workmen against the ordinary hazards incident to machine operation, is a fundamental and most important factor in successful accident prevention work. This is true not only because it insures greater safety to the individual in the performance of his duties, but because it has an excellent psychological effect upon the working forces as a whole, and acts as a stimulus to greater interest and co-operation in the accomplishment of the very desirable result.

It is highly important that considerable discretion be used by inspectors and committeemen in making recommendations for the safeguarding of machinery. Only sound recommendations, after a careful survey to cover an actual existing hazard, should be made, if proper action is to be inspired. Quality, and not quantity, should govern in submitting recommendations. A single unjustified recommendation may cause considerable dissatisfaction on the part of the management or the foremen, and lead to much confusion and delay in having the program properly and effectively carried out.

The safety committees or safety engineers must essentially be enthusiastic and aggressive in their work, but they must also be diplomatic. Criticisms and recommendations should be of a constructive character. When they make a recommendation they should be able to back it up with a sound argument and, if there is opposition, be able to present facts based on past experience,

with the exercise of persuasive rather than coercive methods. They must at all times take a broad viewpoint and consider the situation from every angle, taking into consideration the position of the operating man who is responsible for the production of the department or machine. In other words, all recommendations for safeguarding should be equally satisfactory from both an operating and a safety standpoint. There are three fundamental principles which should be observed in making a safety survey:

1. Existing conditions.
2. Probable occurrences.
3. Methods of safeguarding conditions in the most logical and satisfactory manner.

When it has been fully determined just what is necessary to guard an existing hazard, careful attention should be given to the actual design of the guards. Primarily, they should comply with the laws of the state or community, and with existing company safety standards and specifications; and they should embody all features necessary to make them effective for adequate protection against all existing hazards, but it is important that an effort be made to design guards which will in no way interfere with, or impede operation but will rather increase the efficiency and production of the machines through freer and more skilful operation. Neatness should be a dominating factor and, where possible, the guard should be made to look as much like a part of the machine as possible rather than a clumsy and unsightly guard or fence which occupies valuable operating space and gives the appearance of a greater hazard than really exists.

Substantial construction and proper weight of material are most important from a maintenance standpoint, and all guards should be readily detachable so that the guarded parts may be accessible for repairs or adjustments. A guard not properly designed is an added expense from the viewpoints both of production and maintenance, and such guards will sooner or later cause dissatisfaction and be subjected to abuse with the result that after a short period they will have served their usefulness and be relegated to the scrap heap.

In planning guards for machines, careful consideration must be given to all parts so exposed that a person may come in contact with such parts and be injured. Mere elevation above the floor level, or other location remote from the usual condition, should not be considered as adequate protection if conditions are such that a person might—by the use of a ladder, by slipping, falling, reaching, or in some other manner—be brought in contact with the dangerous parts. All gearing, chain-drives, and shafting, directly connected with the machine, should be completely enclosed with substantial covers. No exceptions should be made to gears or exposures of this character and, in many instances where danger exists, it is highly desirable to guard effectively the point of operation where stock is formed, shaped, or subjected to other mechanical changes. Couplings, set-screws, keys, bolts, and all similar details in moving parts, should be covered or countersunk in such a way as to eliminate the danger of accident, and all unused portions of keyways should be filled so as to present a smooth surface.

The weight and type of material to be used for the construction of machine guards will depend entirely upon the size and character of the part to be guarded, and upon whether or not it is desirable to have the part guarded in such a manner that it can be observed by the operator. In all cases, however, the guard should be of sufficient weight of material and, where necessary, properly reinforced so as to make it substantial and durable. Too often, use is made of material which is entirely too light, and lacking in proper reinforcement. This generally leads to short life and high maintenance cost, or under severe service conditions the guard becomes battered and warped to such an extent that it presents an unsightly appearance and cannot be readily replaced after being removed for repairs. This means additional expense for replacement, or the danger that the guard will be left off altogether and the workman again exposed to a hazard. If maintenance and renewal cost are to be reduced to a minimum, guards must be properly and substantially designed when originally installed, and made as accessible as possible to obviate removal oftener than is necessary. A well designed guard should last as long as the machine and should not be subject to frequent renewal.

The installation of machine guards should always come under the close supervision of the engineering staff and should be placed in charge of a competent man who fully understands machinery guarding.

The power application at the machine, whether direct connected electrically, or belt-and-pulley driven, should be made effectively safe for the operator and others working in the vicinity. The character of the drive must necessarily determine the design of the guard, but the design should embody all the features incident to the best safety practices to eliminate the hazard of coming in contact with the moving parts, and should be applied in such a manner that it will not occupy valuable operating space. It is very important that all machines be equipped with a starting-and-stopping device with locking arrangement which will substantially lock the machine in the "off" position during periods of adjustment or repairs. This can usually be very readily accomplished by a locking belt-shifter for belt-driven machines and, in the case of direct electric drive, by a safety enclosed locking switch conveniently placed near to the machine. In so far as is practicable, all belt-shifters of the same general type should move in the same direction to stop machines; that is, all toward the right or all toward the left. Where direct connected electric drives are used, the power cables within the building and leading to the machines should preferably be run in conduits, with junction fittings for all connections, and no parts from which shock could occur by contact should be left exposed.

In the planning of power-transmission apparatus, which includes all line-shafting, jack-shafting, belts, pulleys, clutches, and electric distribution equipment, every attention should be given to the safety of those called upon to work about this equipment. The same condition should govern as for machine installations, in that mere elevation above the working level or other location remote from the usual working position should not always be considered as sufficient protection. All conditions under which a serious injury may result by persons being brought in contact with exposed parts, should be avoided, or the equipment should embody the proper safety features when installed. Considerable attention should be given to convenience and safe means for

reaching overhead apparatus, such as stairways, walk ways, and platforms, from which the workmen may perform their duties with as little exposure as possible.

In the construction of a plant, or in the installation of machinery and equipment, consideration of safety should take equal rank with construction features. It is well—in fact, highly desirable—that a complete set of safety specifications be prepared before work is started, so that the proper safety precautions and appliances necessary to protect employees from the dangers incident to working conditions and machinery operation, may be provided at the time construction work is planned and machinery is installed.

The advantages of providing, as far as possible, the necessary safety features during the processes of construction work or machinery installation, are obvious both from the standpoint of cost and the convenience of having these features included and made a part of the original contract or regular construction work rather than the inconvenience of adding them in the field after construction or installation work is completed. An endeavor should be made to have all safety features properly installed with the completion of the plant.

Safety specifications of this character should be based upon practical, recognized safety standards and should be drawn up in such form that they may be included and used as a whole or in part for any contract—for construction work, or for the purchase and installation of machinery or equipment. A set of safety specifications should be attached to or embodied in the general specifications when originally submitted to the contractors or manufacturers for bids. In this manner the contractors or manufacturers will be fully advised as to the safety requirements and these features can be included and properly taken care of during the process of construction.

The safety engineer should play a very important part during the planning of a new plant or shop. He should establish a very close relationship with the construction engineer and follow closely and approve for safety all drawings for the plant, shop, and equipment. The general physical lay-out, the arrangement of entrances, routes, and passageways to accommodate employees

entering, leaving, or moving about the plant, should receive careful study so as to eliminate, as far as possible, the hazards incident to crossing railroad tracks and other dangerous areas. Special care and attention should be given to the general arrangement of the shop buildings, the location of machinery, aisles, emergency exits, transmission apparatus, conveying machinery, and means for reaching overhead equipment, as well as the safeguarding of the machinery. Where the size of the job, or the character of the equipment involved, warrants, it has been found very desirable to go over the safety specifications in detail with the contractor before the work is started and during the process of designing, and then inspect the equipment in the contractor's shop before shipment is made. By so doing, a mutual understanding between the contractor and the purchaser may be reached regarding the safety features, and unnecessary expense incident to additions in the field may be obviated.

The co-operation of employees is of paramount importance in a successful campaign against accidents. It is a phase of the work which, of necessity, must be highly developed through the inauguration of strenuous educational measures.

Experience has taught us that fully 80 to 90 per cent. of industrial accidents can be eliminated if proper steps are taken to organize the work properly. It has also taught us that from 70 to 80 per cent. of all accidents occuring are directly attributable to carelessness, either on the part of the workman himself or fellow workmen. It is quite evident, therefore, that considerable attention must be given to educational measures. in which the workman is taught the fundamental principles upon which successful accident prevention is constructed, and to the inculcation of care and forethought which will overcome careless habits. Before this happy condition may be realized, however, the employers must show a willingness and a tendency to maintain a high-grade physical standard and correct the existing hazards. In other words, the employer must indicate and prove his desire to do his part before he can expect the co-operation desired from the men. From the very beginning, plant officials should be impressed with the importance of this feature of the work and every endeavor made to establish hearty co-operation.

In connection with educational activities, to develop the desired co-operative spirit, the following paragraphs offer a few suggestions:

Department Heads Safety Meeting.

1. The general officer of the plant should hold meetings with department heads at least once a month, at which should be taken up and discussed matters pertaining to safety in the various departments, with a review of the accidents and means for preventing a recurrence of similar accidents. It is important that the department head should be impressed with the efficiency and economic value of the movement and the fact that he is the party responsible for the safe conditions and conduct of the men in his department.
2. This monthly meeting should be conducted as a round-table conference in which those participating are invited to discuss, or bring up for discussion, matters bearing directly upon the accident prevention program, or difficulties being experienced. Meetings of this character are productive of many excellent suggestions and recommendations which will prove very beneficial to the department heads in controlling the accident situation in their respective departments.

Departmental Safety Meetings.

1. The department heads should endeavor to get all of the men in their respective departments together for a safety meeting once a month, or as often as possible. These meetings should be held at times when they will not interfere with operation and, in the event departments are too large to assemble all the men in one meeting, group or sectional meetings are suggested.
2. Such meetings are the most direct means of reaching and educating the men and appealing to them for their hearty co-operation and support in the prevention of accidents. Matters of importance, and instructions issued to the department heads at the safety meeting of this body, should be brought to the attention of the men and

discussion invited to stimulate interest and bring forth suggestions. Many excellent and valuable suggestions to correct bad practices or accident hazards are often brought out by the men in this manner which might otherwise go unnoticed for a long period, or until an accident occurs.

3. Minutes of departmental safety meetings should be kept and recommendations by the men referred immediately to the proper officials, central safety committee, or safety engineer, for disposition. If the recommendation, upon investigation, is found worthy of consideration, it should be acted upon as promptly as possible and the necessary corrections made; if not worthy of consideration, the reason for taking such action should be explained to the man making the recommendation, so he will clearly understand and not lose interest.

Training and Apprenticeship Schools.

1. Safety lectures should be conducted in the training and apprenticeship schools to familiarize the men with the fundamental principles governing accident prevention and impress upon them from the beginning the importance, necessity and value of the movement.

Safety Rallies.

1. Where the proper facilities are to be had and arrangements can be made, it is quite advisable to hold safety rallies occasionally for the workmen and their families. These should be conducted in the way of an entertainment, and after a brief address on the importance of accident prevention, two or three safety motion picture reels exhibited, telling a strong story in picture form which all can understand. In this manner many men who are inclined to be careless and take safety lightly can be reached and persuaded through their families. The summer months are best adapted for such rallies, as they can often be held in parks where large gatherings can be accommodated.

Safety Literature.

1. Considerable attention should be given to this method of reaching the workmen and they should be encouraged to read current publications on safety. Two or three concise safety precepts printed on the back of pay envelopes each pay-day, and an occasional insert with an appropriate reminder, will have their effect.
2. Safety bulletin-boards should be conspicuously placed at the entrance gates and in each department, and provided with appropriate bulletins which tell a strong picture story of an accident due to lack of necessary precautions, or carelessness of guards, or how an accident was prevented through observance of the rules.
3. The plant paper, where there is such a publication, should in each issue devote at least one full page to safety, and any other means of reaching the employees through safety propaganda should be given every attention.

METHODS OF THE UNITED STATES STEEL CORPORATION

Welfare in general is a feature in modern industrial activiites which has for its object certain benefits, and the creation of plant and home environments which will contribute to the happiness, health, and comfort of the workers and their families. The attitude of the worker at his daily task is as much a psychological condition as it is a matter of physical strength and skill and will be determined to a large degree by the influences with which he is surrounded both in the plant and in the home. Welfare work should be of a character that influences the life of a worker in such a manner as to establish a co-operative interest in his work, foster within him a spirit of contentment in his home and lead him so to employ his leisure time as not to lower his efficiency as a worker and destroy his domestic happiness, or endanger his standing as a citizen in the community.

So progressive has been the movement, with the realization of its importance, that the majority of our industrial concerns have taken definite steps to organize the work thoroughly. I will

endeavor to outline in a general way the activities of the United States Steel Corporation and its subsidiaries in connection with the welfare of their employees. This is as set forth and illustrated in Bulletin 7 of the Bureau of Safety, Sanitation and Welfare of the United States Steel Corporation.

Organization.

In order to systematize and standardize the work that was being done by the subsidiary companies, the United States Steel Corporation, in 1906, appointed committees to study these matters. A safety committee was appointed, consisting of representatives from the larger subsidiary companies which had already given some study to the subject of accident prevention. This committee has been continued and now meets four times each year, conducts inspections by sending men from one company to another, studies serious accidents and recommends measures to prevent the recurrence of such accidents in any of the plants, passes upon safety devices and makes recommendations as to their use.

The good which resulted from the work of this committee led to the appointment of other safety committees, including the central committee of safety for each subsidiary company, composed of representatives from the different plants of the Corporation. The duties of this committee are similar to those of the safety committee of the Corporation, but with reference to its particular company only. This plan is followed at the plants of the various companies, by the appointment of plant committees composed of important officials of the plant. Their duties are similar to those of the central safety committee but with reference to their respective plants only. At the plants, there have also been appointed safety engineers and the departmental and special committees made up of foremen and department heads as outlined in previous paragraphs, who investigate particular problems relating to safety in the plant and the various departments. The results of the work on accident prevention have been very gratifying. The serious and fatal accidents are about one-half what they were in 1906. It is estimated that approximately 23 000 men have been saved from serious and fatal injury, while

the reduction of other injuries of a less serious nature has been very pronounced—in some instances reaching as high as 97 per cent.

First Aid and Rescue.

Recognizing the fact that with the utmost care and the protection afforded by the most approved safety devices and apparatus, accidents will occasionally happen, the subsidiary companies have made provision for prompt attention to injured men, and skilful care of them.

All the mining companies of the Corporation have first aid and rescue crews composed of employees who are especially trained for the work. This service is purely voluntary on the part of the employees, but before any man is allowed to enter the work, he must have a doctor's certificate showing that he is physically fit for the training and labor incident to it. The system varies slightly in each company, but the general plan is as follows: Four to six men are assigned to each crew. They meet periodically and are trained by the company doctor. The course consists of lectures, demonstrations, and drills. Twelve lessons are usually required to complete the course, and each man is given a certificate after he has qualified. The training of the men for the work goes on continually and many new crews are added each year. A number of crews are assigned to each mine.

At many of the manufacturing plants of the subsidiary companies of the Corporation, men are trained in first aid work. The training is similar to that given in the mining companies. The primary object of first aid is to furnish an aseptic or clean dressing that will prevent infection in the wound.

As a necessary adjunct to first aid and rescue work in both mines and mills, emergency hospitals, completely equipped, have been provided. All cases of injury, no matter how trivial, are sent to the emergency hospitals or stations, where treatment is given by competent surgeons or trained nurses. Whenever the accident is of a serious nature, the injured man is taken to the emergency station, where first aid treatment is administered, and he is then transferred to the nearest hospital.

Relief.

Recognizing the fact that the burden of caring for the injured should be borne by the industry, the United States Steel Corporation established a voluntary accident relief plan, which was put into force before any such system had become law in the United States. This plan is purely voluntary and was put into operation by the Corporation in May 1910, and is for the benefit of all employees injured, and the families of employees killed, in the service of the subsidiary companies. The funds required to carry out the plan are provided by the companies, with no contribution whatever from the employees. Relief is paid, regardless of legal liability and without legal proceedings; even application for relief is not required. This plan of relief is still in effect in those states where workmen's compensation laws have not been enacted.

Sanitation.

The work in sanitation has been organized in a manner almost identical with the safety organization, except that the sanitation committee is chosen from the presidents of the subsidiary companies with an officer of the United States Steel Corporation as one of its members. This committee administers the work through a sub-committee composed largely of technical representatives from each of the subsidiary companies.

In sanitation, many improvements have been made in the proper investigation and observation of water-supply and distribution to the employees. All sources of drinking water are analyzed periodically and great care is taken to prevent possible pollution by surface water or otherwise. The most modern sanitary methods are employed in the cooling and distributing of the water, including the installation of sanitary drinking fountains, and the common drinking cup has been practically eliminated.

The committee has prepared specifications covering general sanitary requirements and these are followed by the subsidiary companies when installations are made. An important requirement in these specifications is that no wash-basins shall be installed. Facilities for washing the face and hands shall be such that employees must necessarily wash from the flowing stream.

This may seem radical, but we think it important, in order to avoid any possible danger of spreading disease. Good toilet facilities have been installed at all plants and mines—these facilities usually including shower baths. A number of swimming pools have been built for the general use of the people in the mining towns.

In Alabama, where one of our mining companies conducts its operations, the conditions are favorable to mosquito breeding. This company is doing much to prevent the spread of malarial fever. Streets and alleys are properly drained; pools and lowlands are drained or filled in, where practicable; otherwise they are covered with crude petroleum. All known methods of fighting the mosquito are used. By these methods the number of cases of malarial fever has been greatly reduced, and the comfort of the people living in the camps has been increased.

Metal garbage cans equipped with tight fitting covers are placed at the rear of each house in the mining camps, and at convenient places throughout the mills. Garbage and other waste materials are collected periodically and burned.

Some of the subjects of which the sanitation committee is now making a study are, occupational diseases; mine sanitation; proper ventilation in plants and company houses; provisions for proper heating and lighting systems in plants; provisions for regulation of milk supply; dust removal at plants, including roadways.

Plant Restaurants.

The success attending the operation of plant restaurants already installed by the subsidiary companies, and the benefits resulting therefrom, have encouraged many more installations of like character in other plants of the subsidiary companies. In addition to giving the employees an opportunity to secure good, wholesome food at moderate cost, there are other benefits more diversified in character than might appear at first thought. These can best be summed up by quoting from an article of one of the officials of a subsidiary company, which has given considerable attention to the installation of restaurants within its plants:

"When laboring overtime on break-down or emergency work the employee can secure a full meal at his usual dinner hour. Workers in exposed situations during severe weather can be refreshed by a portion of hot soup or coffee.

"When exhausted by heat and physical exertion in warm weather, a refreshing draught obtained when most needed frequently enables an employee to return to work with renewed vigor when otherwise he would be incapable of useful exertion for a considerable time. The aromatic bottled drinks furnished at practically all of our restaurants seem to supply the necessary stimulation to overcome abdominal cramp among workers laboring in heated positions, the cramp being frequently superinduced by injudicious drinking of water when one is suffering from stomach derangement or careless exposure of the person to strong currents of air.

"The burden of the housewife in the daily preparation of the dinner bucket, following the serving of an early morning meal is eliminated. Where father and son have both to be provided for, as is often the case, the burden is by no means a light one.

"When the wife is ailing or away from home, or sickness occurs among the little ones, the breadwinner may have to undertake the unfamiliar *role* of household cook—sometimes with disastrous results to his own internal well-being, not to mention that of his family. Where a mill restaurant is available, a half-hour earlier start from the house secures him an inviting breakfast at a moderate cost.

"An equally important consideration is the selection of the contents of the dinner bucket. The most desirable forms of food are not always adapted to packing, nor will they retain their freshness and palatability after standing for several hours in unsuitable temperature, as is often their fate. It is not uncommon in rolling mills to see a large proportion of the contents thrown away because of its unpalatable or uninviting condition. As a further argument to prove the inadequacy of the packed lunch when put up by inexperienced housekeepers it may be stated that, not to speak of the questionable assimilative value of certain articles and combinations of food frequently found therein, fairly numerous cases occur where men, after consuming the contents during the noon period, visit the restaurant in the afternoon to purchase a 10- or 15-cent meal.

"For the unmarried men lodging in rooms—and especially those who do not or cannot obtain their meals at a boarding house—the higher prices prevailing in public restaurants is a condition not always easy for the young man to meet. Here again the problem of the dinner bucket has to be confronted, with the added difficulty, however, of getting the bucket filled with the things one likes, or that seem to best meet his particular requirements. The unmarried man and the foreign day laborer are usually good patrons of that section of the mill restaurant counter where such tasty items as fruit, cake or dessert provide a welcome addition to the somewhat monotous fare of the boarding house."

In addition to numerous restaurants which have been installed in the plants of various companies where food is served, considerable attention has been given to rest rooms and dining-rooms of various descriptions, so that employees may retire to a clean and sanitary place remote from the operating departments, to eat their lunch.

Musical Organizations.

Often considerable musical ability is displayed by the workmen at the various plants, and wherever sufficient material is found, brass-bands are organized and male chorus singing is encouraged, the equipment and maintenance of these organizations being mainly at the expense of the company. By this means, musical entertainment is provided at the lectures on safety, and at the other gatherings, and becomes an important and enjoyable feature of the community life.

Gardens.

The United States Steel Corporation and its subsidiary companies have done much to encourage garden work among the employees. While this was considerably accelerated during the period of the war, it was not purely a war measure. For many years the subsidiary companies have offered special inducements to the employees to utilize unoccupied land for the raising of vegetables. This was done usually in connection with unused ground adjacent to the plant, but frequently, particularly in the mining villages, like encouragement is given to the employees for the development of home gardens. In the development of the plant gardens the company usually plows the ground at its own expense, plots it out and then offers prizes for the best gardens. The companies have also rendered considerable assistance to the employees in the purchase of garden tools, seeds and other equipment. The results which have been obtained by the employees in developing these gardens have been very pronounced and the yields in money value have extended into thousands of dollars.

Clubs.

Many of the subsidiary companies have provided commodious and well-equipped club-houses for the use of their employees,

members of their families, and friends. The features are: Dormitories, reading-room and library, gymnasium and swimming pool, baths (tub and shower), auditorium and dance-hall, billiard-and-pool rooms, bowling alleys, basket-ball, halls with motion pictures, lectures, concerts, smokers, etc.

Reading-rooms are supplied with the current magazines and periodicals, daily papers and a good assortment of books. The social entertainments are a feature of the clubs. The affairs of the clubs are handled by the members themselves, in the usual way. Gambling and intoxicating liquors are prohibited.

The subsidiary companies pay all taxes and insurance and furnish heat. All other expenses are borne by the club members, the initiation fees and monthly dues being very small. In some cases these dues are fixed in proportion to the wages of the men.

Visiting Nurses.

Visiting nurses are employed by the companies in a number of districts. The service is confined strictly to nursing, carried on under the direction of the employing company, and does not apply to the work, similar in character, directed by benevolent societies composed of the employees themselves. The assistance rendered by these nurses is of both professional and practical value. The object of this service is to improve the general health and increase the happiness of the employees and their families. The principal duty of the nurse is to give instructions in those things which will enable the employees to better their condition mentally, physically, and materially. Her services are offered free by the company to the employees and their families, but are not forced upon them; she is not permitted to visit the homes of the employees upon any occasion unless requested to do so by a member of the family. But opportunities of giving instruction and advice in matters of household sanitation, economical purchasing of home necessities, care of children—especially in infancy—and the numerous and perplexing problems confronting the mother, are presented through her ability and willingness to help in cases of sickness. Therefore, the nurse must be skilled in her profession, and must also be tactful and of a pleasing personality, so that she will be a welcome visitor in the homes, in

whatever capacity her presence may be required. Her genuine interest and her desire to be of assistance in time of trouble, win the confidence of the people, and she becomes the counsellor, helper, and friend from whom they seek aid and advice, knowing that any problem submitted to her will be given careful consideration. The work of these visiting nurses may be briefly outlined as follows:

1. Attending the sick.
2. Giving instruction in personal and domestic hygiene and in domestic science.
3. Helping the families to deal with financial, physical, marital and other domestic troubles.

Practical Housekeeping Centers.

At some of the plants and mining towns of the subsidiary companies, special courses in practical housekeeping are arranged by the companies for the benefit of the wives and children of the employees. Special instructors, usually the visiting or district nurses, are employed for this purpose.

Some companies provide houses or special rooms and equipment for the maintenance of this work, which includes all phases of the preparing and cooking of foods, the care and feeding of babies, dressmaking, and many other phases of domestic science, even to the proper method of making beds.

The houses usually selected for the work are plain and simple in style, containing either three or four rooms—the type of dwelling occupied by the miners or other employees. They are furnished simply, but neatly, the furnishings selected being such as are within the means of the employees. The purpose is to furnish an object lesson for the wives and daughters of the employees by illustrating what may be accomplished in the way of convenience, comfort, and attractiveness within their limited means. These houses serve also as homes and headquarters for the nurses.

These household centers are becoming important factors in the communities where they are established. The families of the employees welcome the idea of the centers and refer all sorts of

problems to the nurses. In fact, the nurse becomes a sort of family counsellor.

The following are some of the activities carried on at these practical housekeeping centers:

1. Classes for children in sewing, cooking and housekeeping.
2. Meetings for the women of the community for instruction in infant welfare, cooking, sewing, housekeeping, public health and hygiene.
3. A club for the small girls of the community, under the direction of the nurse. These clubs are self-governing, with constitution, by-laws and officers.
4. A club for the boys of the community, under the leadership of a young man, with definite rules covering the conduct, activities, and qualifications of the boys for membership. The boys help to formulate these rules and therefore feel themselves bound to enforce them.
5. A club or association, under the direction of the nurse, for women employees of the company, to afford those women employed in domestic service or similar isolated duties opportunities to mingle socially with the other members of the community.

Playgrounds.

The many good results obtained through the establishment and maintenance of playgrounds at the various plants and mines of the subsidiary companies, justify the attempt to provide attractive places for the children, and encourage further efforts in this direction.

In many cases the companies are compelled, because of the immediate need for playgrounds in certain localities, to utilize whatever ground may be available; thus, a neglected piece of property is cleared of its rubbish and equipped with the more popular playground apparatus, and it immediately becomes an attractive place for the children. Many of the playgrounds are located within the plants or works, frequently adjoining the mill yards. Occasionally the playgrounds are turned over to the municipal authorities and are operated by them, the company contributing to the maintenance and up-keep.

The children appreciate the advantages afforded by these pleasure grounds and are enthusiastic in their patronage, the average daily attendance during the summer months in the 148 existing playgrounds throughout the companies being approximately 18 000. These recreation grounds and amusement facilities are not restricted to the use of the employees' children, but are free to the entire community.

The companies employ competent instructors—often the company nurse in the vicinity is the person best fitted for an instructor—to supervise the grounds and look after the children, and it is a source of great satisfaction to the busy mothers of large families to know that their children are safe and are being amused and instructed. Always, heretofore, there has been the difficulty of keeping the children out of the streets and alleys, where they are in constant danger from the traffic.

The teachers join in the games of the children, making congenial playmates as well as good leaders, and tactfully encourage the games most conducive to health and mental development. Also the children are taught arts of various kinds—basketry, sewing, and various other handicrafts. Frequently the young women in the vicinity of the plants or mines, volunteer their services to the company during their leisure hours and are most helpful in directing the interest and attention of the children to worth-while games and beneficial recreation. The children are apt and interested pupils and, under the leadership of these older girls and instructors, their abilities develop along many lines which will prove of practical value to them in later life. Moreover, in their desire to excel in their games, there is the stimulus of friendly rivalry.

Near some of the playgrounds are welfare houses or nurseries where the children can go during the colder months and where the nurses in charge make things cheerful and inviting for them. Gradually this work assumes many phases—the formation of clubs, classes in various branches of kindergarten work, and, finally, practical housekeeping—and usually we have found that the children are glad and eager to take advantage of such opportunities, and join in the activities afforded them with genuine interest and enjoyment.

A popular and attractive feature is the wading pool in the playground, always refreshing to the youngsters on hot summer days. There are large swimming pools, also, for the older boys and girls and the adults; but very often these are located apart from the playgrounds, near the mills, or in connection with the company clubs, where they are easy of access should the men desire to use them before or after working hours.

Adjoining the playground, the company provides athletic fields for the older boys where baseball or other outdoor sports may be enjoyed. At the present time there are 118 such fields and, apparently, they are as popular with the older boys as are the playgrounds with the smaller children.

In each of these playgrounds the company has installed toilets and washing facilities adequate to take care of the average daily attendance. Sanitary drinking fountains are provided, also, and all these facilities are readily accessible so that the children may obey the slightest inclination to use them.

The influence of such wholesome outdoor life upon the health of the children cannot be overestimated. It strengthens them both mentally and physically, and the teachings of the instructors are assimilated naturally and are applied to the everyday life of the children, resulting in the betterment of their home conditions.

Dental Clinics.

The first attempt at dental work among employees and their families was made by one of the southern subsidiary companies in the fall of 1915, with the employment of a dental surgeon to care for the teeth of children in the various schools maintained by the company. An inexpensive, portable, dental outfit, such as is used in the United States Army, was secured, and the dentist moved from place to place, usually establishing his clinics in the dental dispensary closest to the school to be covered. During the school year of 1915–1916, the teeth of every child in the schools (both white and colored) were examined by the school dentist and any necessary dental work was performed—the total representing about twelve hundred extractions and three thousand cleanings. Unquestionably, the children are benefitted in health, and the work proved immensely popular. As an illustration of its

popularity, the following is of interest: Definite instructions were issued that no dental work was to be done for any child without written permission from the parents and, during the entire school year, in not a single instance was permission refused.

With the beginning of the school term of 1916, a second dentist was engaged to assist in this work, and a tooth-brush drill was established in very school. Each child in both the white and colored schools was required to furnish his own tooth-brush and cup, these articles being on sale at our own commissaries at actual cost. Dust-proof cabinets were placed in every school room for the storage of brushes and cups. The tooth-brush drill is the opening exercise of every school every day and the average time required is 12 minutes. The drill is popular with the children and is one of the real events of the day.

In December 1916, a permanent dental clinic with a modern, high-class equipment costing some $900, was established at the Fairfield Medical Dispensary. Originally the work at this clinic was limited to treatment of accidents occurring in line of duty, and consisted of the replacement of injured teeth and repair of jaws. The work proved highly satisfactory and the new method much more efficient than our former plan of referring such cases to outside dentists.

In September 1917, dental clinics were established at Docena, Edgewater, and Bayview. At Docena the dental clinic was placed in the medical dispensary, but for lack of room this plan could not be followed at Edgewater and Bayview, and tenements were used for the purpose. An excellent equipment—comprising electric engines, fountain cuspidors, hydraulic chairs, electric sterilizers, first-class dental cabinets, and dental operating instruments of the highest grade—was provided for each clinic, at a cost of $900 to $1500 for each installation. A dentist was employed for each clinic on a regular monthly salary basis, and regular office hours were established—three days each week for white patients, and three for colored patients.

The office hours are 8 a. m. to 4:30 p. m. daily. The clinic is open also two evenings in the week, from 7 to 9 p. m., to accommodate employees who cannot have the necessary work done during the day.

A schedule of charges, averaging 50 per cent. less than the charges made by city dentists, is posted in every dispensary. When an employee or a member of his dependent family applies for treatment at the dispensary, his mouth is examined by the dentist and an estimate made of the cost of the required work. This estimate is the form of authority for deduction from the pay-roll, and it is signed by the employee and turned in to the timekeeper's office. Payments may be made in monthly insallments if the employee so desires.

In March 1918, a clinic was established at Wenonah, located in the medical dispensary, and in June 1918, a similar clinic was established at Ishkooda. On November 1, 1918, clinics were opened at Johns and at Ensley, the clinic at Johns being located in the dispensary at that place and the one at Ensley in the new emergency hospital just being completed. These eight dental clinics handle an enormous amount of work in a manner satisfactory to the employees and the company and, even at the low rates charged, the clinics are self supporting. The dentists in charge of the clinics have been selected with care and are employed on a straight salary basis, their work being under the close supervision of the chief dentist and of the superintendent of the health department.

Employees and their families no longer need to travel long distances from our mining towns to the city to have dental work done—usually at exorbitant prices—and thus much time is saved to the company. The dental force works in close co-operation with the medical organization, and all cases showing symptoms of local infection are referred to the dentists, and also all cases where the physical examination for employment discloses bad teeth. The local dental clinics also attend to all work for the school children, which was formerly done by the traveling dentist.

The success of this service has exceeded all expectations and the only difficulty is to furnish a sufficient force to cover the work.

Americanization.

The subsidiary companies of the United States Steel Corporation have put forth an attempt to Americanize their foreign-born workers, and success is attending their efforts. The first

step is the teaching of the English language. Classes are conducted by many of the companies either in the rooms in the mill buildings, or, through the co-operation of the local school authorities, in a school-room on two or three evenings of each week. Frequently employees of the companies volunteer as teachers, and lessons begin with the pronunciation of names of the objects most familiar to the men in their daily work. These lessons are supplemented by posters and bulletins posted throughout the mills and mines of the companies. As their knowledge increases, many of the men attend the local public night schools or Y. M. C. A. classes, which are in part maintained by the companies through contributions made at regular intervals; and when the course in English is completed, many of the men are competent to take out their first citizenship papers. In one locality this Americanization work is carried on for the sole purpose of assisting the men to secure their naturalization papers.

While the actual task is under the supervision of an Americanization committee our subsidiary companies in the vicinity contribute freely to the maintenance of the schools and to the teaching staff. The buildings, lights, heat, and janitor service are furnished by the school-boards, and everything possible is done to make the schools attractive to the foreigners. The men are taught to read and write and, to insure their interest in the lessons, they are encouraged to discuss daily events and to read the newspapers. When they have acquired a sufficient knowledge of English, many of the men apply for first papers; and then they receive instructions to fit them to pass the Government examinations for securing their final papers. Last year, in this locality alone, there were some 400 men enrolled in the various classes in regular attendance at the schools. In another district the night school enrollment numbered 2366.

Among the women and children, much of the Americanization work is in the hands of the visiting nurses. The work covers a wide field, but through the children's club and home-making classes these nurses are given opportunities to inculcate American ideals in the minds of the boys and girls, and through them to reach the parents, who are glad and eager to learn from their American neighbors. At many of the practical housekeeping

centers classes are formed for the foreign-born women, where they are taught the proper care of their children and homes. Here they acquire some familiarity with the language, as well as a knowledge of American standards of living.

Many different methods may be advocated for the Americanization of our foreign-born population, but no better method can be employed than the training of the public schools and the intelligent use of such other facilities as are already in existence in the industrial centers. The foreigner feels confidence in the school because his children attend it and he knows that it is a democratic institution, without restriction as to race or creed and, above all, free from patronage. He is not timid about entering the building, but is at ease, feeling that it is his right to enter the place where his boys and girls are receiving their training. Then, also, in the school building are other facilities for Americanization that cannot be afforded merely by the night classes for the study of the language. The school library and the opportunities for social gatherings are large factors, and through them he learns something of American modes of thought and action. The foreigner should always be encouraged to attend the night school. The school building, if carefully planned, will be attractive and inviting to him and he will feel pleasure and pride in his relation to it. In isolated districts, such as lumber camps and railroad yards, especially, the schools in the vicinity should extend their activities in an effort to reach as many people as possible.

Above all, however, we should encourage and help the foreign-born laborer to feel that America earnestly wishes him to take advantage of the opportunities offered him. In this way only can we hope to attain the best results.

DISCUSSION

Mr. Albert R. Raymer:* I have been very much interested in the paper given us to-night on safety first, and allied subjects. We have been following this work very closely in its application to railroads. Splendid results have been accomplished and I want to express my appreciation of the paper and also of the motion pictures.

I think we hardly appreciate, at least not without giving it particular attention, the valuable work that is being done along safety first lines, particularly in conserving human life. As has been brought out to-night, the greatest difficulty seems to be to get those who are particularly exposed to danger to take up the work seriously. I was glad to see this point stressed to-night.

The thanks of the Society are due to Mr. Schultz for the very splendid paper he has given us.

Mr. Arthur E. Crockett:† I have been more or less in touch with the safety first movement from its earlier days and have watched its development with a very keen interest. Prior to the war, when the United States Compensation Commission was formed, it was my pleasure to meet the Chairman of the Commission, Mr. R. M. Little, who enthusiastically spoke of the work that was being done in safety work in the United States navy yards and arsenals, and the development of this work I watched with deep interest. Of course, safety work had gained considerable headway in this country, in various manufacturing plants, before our Government took up the question and it often seems strange to me that our Government is so slow in taking hold of the work in which it should really be a leader, particularly when it comes to human life and its conservation.

I believe the matter of safety and welfare, so ably presented by Mr. Schultz, will advance with rapid strides. I further believe that every one of us here to-night will leave with a more determined purpose to help advance not only safety work, but also welfare work.

*Assistant Chief Engineer, P. & L. E. R. R., Pittsburgh.

†Forging Engineer, Jones & Laughlin Steel Co., Pittsburgh.

MR. JOSEPH HENRY WHITE:* For the past three years I have been in South America identified with the welfare work of one of the largest copper mines there and it might be in order to say just a few words about my experience in the southern continent.

The welfare work which was undertaken there covered a wide scope, including housing, sanitation, recreation, policing and safety work. One of the wags of the camp said the Welfare Department did everything from feeding pure milk to anemic children to keeping liquor away from thirsty adults.

One of the most important, and in some cases hazardous, parts of the welfare work was enforcing the prohibition regulation. At this particular camp, prohibition had been in force since 1909, so that we were a little ahead of the United States in that respect. In enforcing prohibition away up on the Andes about eight thousand feet above sea level, some dealings were with a particularly lawless class of people, as some of the worst bandits and outlaws in Chile, when driven out of large cities by the police force, took up the profession of boot-legging liquor to the camp. The term boot-legging does not accurately express their method. A rather interesting garment was used to carry the liquor. It consisted of a garment with about 12 or 14 pouches —worn on the body as we wear a vest—and each pouch was just large enough to hold a quart of "Canadian Club."

An average of $5 per month per person was expended on welfare work. With about 12 000 people on the property this made an aggregate monthly expenditure of about $60 000. I make a point of this because one of the interesting results noticed was that as more money was spent on recreation it was found necessary to spend less on liquor prevention.

Last year there were two striking incidents which went to prove the value of welfare work. A serious labor strike, that threatened the entire nation of Chile was averted. A great many workmen's clubs had been organized on the property and at the time this strike was threatened all over the country the officers

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of these various clubs came voluntarily to the General Manager and assured him of the loyal support of their members. In that same year there was a serious epidemic of typhus fever which raged more or less throughout the country, and our camp escaped without a single case. The same, however, did not apply to the Spanish influenza. There were about three thousand cases of that but in our camp it was in a mild form, very few deaths resulting.

I enjoyed very much the paper presented by Mr. Schultz and am very glad to have been present and had the opportunity of hearing it.

POST-WAR CONDITIONS IN EUROPE, WITH SOME COMPARISONS OF AMERICAN AND EUROPEAN BY-PRODUCT COKE-OVEN PRACTICE

By John I. Thompson*

SCOPE OF PAPER

It was my good fortune to visit England, France and Belgium in company with Mr. A. W. Grant, Jr., during the months of April, May and June of this year, returning by way of Norway and Sweden. Perhaps at no future time will conditions be just as we found them and it is not likely that such a journey will be so interesting again. The armistice had been signed but six months, the armies were not yet demobilized, and although the countries were technically at war, it was possible to go almost anywhere if one had sufficient patience to fulfill all the harassing requirements as to passports, and was willing to endure all sorts of inconveniences and discomfort.

It seems to me that it would be much more profitable to the majority of those present to-night if I would not confine myself to a discussion of what I saw with reference to the branch of engineering in which I am engaged, but would tell you something of my impressions of conditions of more general interest in the countries which we visited. I have also chosen to touch briefly, without going into great detail, on some of the things that particularly impressed me in comparing European with American by-product coke-oven practice, as I saw it.

LABOR CONDITIONS

The first question that is asked by an English manager when you visit his works is, "What is your labor situation in America?" They tell you their men don't want to work, they want more holidays, they want shorter hours, labor leaders limit the amount of work a man may do in a day, they want more pay, and at the time we were there their plea was for more alcohol in their

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beer and more beer. If unionism means for our country what it means for Great Britain, I am frank to say I am not in favor of it.

The union leaders seem to take the attitude that business can stand all that the organized workmen can get, without reasoning that eventually this burden returns to the workmen in the form of increased cost of the necessities of life. If a miner demands more pay and takes out less coal, he should not complain if the cost of everything he eats and wears goes up.

In England, labor organizations have so reduced the amount of work which they will permit a man to do that it is alarming the leaders of thought in all walks of life. And their false economy leads them into all sorts of folly. For instance, the riveters on certain classes of ship-building will not use modern machinery. They figure that there are so many rivets in the world to drive. If one man drives more than his share, his neighbor will have fewer rivets to drive and will be thrown out of work and he and his family will starve. I was talking with a coke plant superintendent. His coke was pushed from the ovens and quenched by hand on a level wharf in front of the ovens, and then forked into cars. The men were all unionized and determined the capacity of the plant by dictating the number of ovens they would handle in a day. I asked the manager why he didn't put in machinery to handle the coke and he said that the union would demand that the company keep the regular number of men on the job anyway, on the theory that the plant had to support these men or their families would suffer. We were told that the only method that could be employed to obtain modern equipment would be to abandon the plant, pay off the men and, after the plant was rebuilt, hire a new gang and make a new start with a clean slate.

Any nation whose economic life is throttled by such false thinking and unpatriotic actions on the part of a large percentage of its population cannot compete with a nation that is willing to work. No matter how low Germany may have fallen, she will regain economic supremacy if her people are willing to work and to save. And England is certain to lose the position she occupies unless her people go to work and produce. We

engineers should preach the gospel of a hard day's work for every able-bodied man and woman, and we should do everything possible to increase the productivity of every worker. No right-minded man has any quarrel with the principle that every worker, whether he work with his brain or his hands, should have a reasonable amount of leisure, but too much leisure is more harmful to most of us than too much work. If we love our country we must all produce and we must also save; the prosperity and wealth of our nation depend on this. No other program will reduce the cost of living so surely, and all other means are of secondary importance.

It was very difficult for me to judge labor conditions properly in France, due to the fact that I could not understand the language. At the time we were in Paris, about June 1, there was considerable labor unrest. The subway employees were on strike, and during this time I can remember very vividly that the taxi drivers were more insolent and avaricious than ever. They demanded a tip before they agreed to take you and they refused to take you at all if your destination didn't suit their fancy. They acted very much as though they wanted you to pay the fare, give them a tip and then walk to your destination. Once in a while you would find a human being among them. The labor leaders seemed to belong to some sort of international socialistic society, and their principal plea was that the peace terms were too hard on their German brothers. We were told that the soldiers, who had fought in the trenches for a few sous a day while those who were making the trouble had worked behind the lines in safety for high wages, were not in sympathy with the movement and could be relied upon to put down any disorder.

In Belgium the situation was different. Many thousands of men were out of employment and were still being rationed by the government. Employers complained that the people were demoralized as a result of the war. They did not want to work. They had been supported by charity so long that their usefulness had been largely destroyed.

While we are discussing labor, it may be of interest to you to know that of all the workers we saw in Europe, the German prisoner moved more slowly and accomplished less than any

other. If he was told to move, he complained of being brutally treated, and the result was that in the war area wherever you saw him he was wasting his time among the ruins for which his nation was largely responsible.

COST OF LIVING

I was very much interested in noticing the cost of ordinary necessities of life in the different countries.

The cost of living in the hotels in London was much higher than in New York and accommodations were much more difficult to obtain. I remember being forced to spend a night in a private residence. The proprietor was financially embarrassed as a result of the war, and as the house was large he told us that they were taking advantage of the congested condition of the hotels to make a little money. He wasted considerable of my time raving about profiteers in general and the labor unions in particular, and called my attention to the fact that coal for domestic use was the equivalent of $17 a ton at that time and the miners were demanding higher wages and shorter hours. We found rooms in a hotel the next day but paid him a bill of about $15 each for breakfast and one night's lodging. I suppose this Londoner is still raving about other profiteers. Many a weary traveler has spent the night in a bath-room, using the tub for a bed. In fact, I am told that bath-tubs make comfortable beds. On more than one occasion I rather envied the man in the bath-room, because he was the only man who could have the luxury of a morning plunge. Bath-tubs are not so plentiful in European hotels; and, although one can get a bath when necessary, it is not so convenient, as a rule, as in our large hotels. This congestion in the hotels we encountered everywhere except in Brussels.

In England, sugar was very scarce and the quality very poor. Butter was served only at breakfast and we ate no white bread. I shall never forget the look of disgust on the face of an English waiter when I asked for buttermilk; and in the better restaurants one must ask for a glass of water if one would have it because it is customary to drink something stronger at meals. Meat was scarce, but could be purchased in the restaurants, and the fish was delicious and plentiful. In general, the cost of food was

considerably higher than in this country, and the cost of clothing and shoes about the same.

If the necessities of life were costly in England, they were higher in France. Food was frightfully expensive anywhere, but the prices in the best restaurants were exorbitant. A very ordinary meal for one person, such a meal as could be purchased in a first-class restaurant here for $2, would cost the equivalent of $6 to $9 in any of the good restaurants in Paris. A very good meal would cost as high as $15. In the markets ordinary chickens sold for about $5 apiece, and beef or bacon at about $1 a pound. Real white bread was not served. Saccharin tablets or water sweetened with saccharin was used instead of sugar.

I was surprised to find that food was much less costly and more plentiful in Belgium than in either England or France. The only pure white bread we ate in Europe was in Belgium. Sugar and cream were served with the coffee. Butter was plentiful. We saw more candy shops in Brussels than anywhere else and they seemed to be well stocked. Prices were not much higher in the hotels and restaurants than in New York.

With the wages averaging about 30 per cent. lower for common labor and 50 per cent. lower for skilled mechanics than in this country, it seems to me that the people of these countries, and especially France, must have a very difficult time to make ends meet. I cannot tell you what a wonderful relief it was to get back to this land of plenty—of sleeping cars and bath-tubs and ice water.

WAR LOSSES

It is not my purpose to discuss the statistics of the war, but to give you some idea of the impressions I received in traveling through the countries of our Allies.

Frenchmen will invariably tell you that, for France, the war was lost. In man power her loss was relatively over 10 per cent. greater than that of Germany, and the monetary cost of the war per capita was exceeded only by Great Britain. From an economic point of view, Frenchmen believe that, as a result of the war, America is relatively richer and stronger, Great Britain next, then Japan, Italy, Germany, Austria, and last of all the

great powers, France. I believe their judgment is pessimistic and I am sure we all hope that, as the years go by, France will recover from the effects of this terrible struggle; but no one who has seen the condition of Northern France can fail to sympathize with her people.

I was astonished at the activity of the shops and the mills of Great Britain at a time when our industries were working at reduced capacity. Almost without exception her steel mills were well supplied with orders, and the mills were there to handle the orders; but in France the greatest industrial districts were destroyed. Even Belgium was not so totally wrecked as France. Many of her mills and factories were stripped of everything that could be of value to Germany in the prosecution of the war and there was much wanton destruction; but in France large areas are totally destroyed. The battle swept over Belgium, but the contending armies literally tore off the face of the earth in Northern France.

We visited the ruined city of Rheims and saw the remains of the Cathedral, which was built in the thirteenth century and in which the ancient kings of France were crowned. To my mind it is ruined beyond repair. The roof is gone and the beautiful windows are all shattered, hardly a particle of glass remaining in the frames. One of the towers was supported by timbers, and thus kept from falling. Photographs do not depict the extent of the ruin. Shells have burst against the wonderfully carved walls and doorways and have chipped off the surface of the stone. The finely carved figures and faces are marred so that they can never be repaired. The Cathedral of Rheims to-day bears the same relation to its former self as a skeleton does to the human body of which it once was a part. The city of Rheims is a complete wreck. I believe that there is not a square foot of wall or anything that remains standing, that does not show the marks of exploded shells.

We visited the towns of Amiens, Arras, and Lens, and the villages on the road between these towns. We passed beyond Lens into the territory occupied by the Germans during several years of the war and visited what remains of the largest coke plant of France at Pont a Vendin. Lens was the center of a large

coal field and a city of some importance. It was occupied by the Germans during the war and was one of the objectives of the British Army. It stands just beyond the famous Vimy Ridge, where the Canadians won immortal fame. The city was protected as much as possible by the British until it became a military necessity to bombard it, which they did day and night for over a year. It is not possible to describe the vastness or the thoroughness of such destruction. One must see it to understand it. Not a wall in Lens is standing over a few feet high; not a timber remains whole. I was told by a man who had lived there through this bombardment that the civilians were forced to remain. They lived in the cellars. They said they "were in hell and made the best of it." Hundreds were killed.

The coke plant of Mines de Lens is almost a complete wreck. What the English did not destroy by shell fire the Germans deliberately destroyed or carried away. The copper was carefully taken out of armature windings and the insulation left on the floor. The machinery was wantonly destroyed in its vital parts where no shell had struck. We saw large bell and spigot gas mains in the cellar of the by-product house under a concrete floor which were broken and the lead carefully removed from the joints. The floor was intact showing that shells had not penetrated there. The superintendent lifted a wooden cover from a small valve pit about thirty inches square and showed us a valve about three inches in size that was destroyed. The valve flanges were still fastened to the pipe, but the body was broken and the brass removed. The switchboard in the power-house was gone.

The coal mines in this district will probably not be operated for years in most cases. They are very deep and the shafts go down through water-bearing chalk, and it is the belief that the shaft linings are broken. The mines are full of water. The head houses and machinery are a pile of twisted steel and their broken parts clog the mouth of the mine shaft. After seeing this once prosperous region, one is not surprised that France demanded the coal of the Saar Basin.

There may have been some justification for the removal of materials required by the Germans in the prosecution of the war,

but there are numerous evidences of fiendish destruction for the purpose of crippling the industry of a rival. We visited a little plant in Belgium which they had totally destroyed. The plant consisted of two small blast-furnaces, a puddling mill and a rolling-mill. I have lived around blast-furnaces all my life, but the destruction of this plant was so complete that I could not tell what sort of plant had been there. Every pound of steel and iron had been removed, and even the foundations were blown up. There was a new battery of coke-ovens here which had just been completed when the war broke out and which were never heated up. The destruction of the plant had been arrested by the Allied armies and the coke-ovens were intact and as perfect as when they were built. The coke conveying machinery was cut off clean where it left the coke-ovens and entered the blast-furnace plant. The apparatus of the coke plant was marked with numbers referring to the German bookkeeping system in which its ultimate destination was recorded.

Although the Belgian cities and towns are for the most part intact, many factories were destroyed deliberately. The Germans apparently had such confidence in their ultimate victory that they generally gave receipts for the things they took. The Belgians call these receipts "scraps of paper," for they are now worthless. Private residences were robbed of cotton mattresses, brass hardware and fittings of all sorts. The Germans are said to have had machinery and equipment catalogued so that they knew exactly where to get what they wanted. Motors, pumps, and cast-iron wharf plates seem to have been required from the coke plants.

Without having any measure of the exact losses, my impression is that France has suffered much more than Belgium. The very soil of a wide strip of Northern France is destroyed. The shells penetrated and then blew up the subsoil and destroyed the productiveness of the land. No man with a heart can look at such a sight without emotion, but all the time I was in France I did not hear a Frenchman whine. They are going stoically about their business; and I have faith that ultimately they will recover, although the scars on the face of France will not be erased in generations.

BUSINESS CONDITIONS AND POSSIBILITIES

When the armistice was signed and as soon as permission was granted to travel, France and Belgium were flooded with salesmen offering all sorts of things to a bewildered people. As a French banker expressed it, "They came too soon for us." At the time we were there—six months after the signing of the armistice—there was very little being done by American salesmen. Put yourself in the position of a French or a Belgian manufacturer whose plant, and perhaps the town in which it is built, is a total wreck. The peace treaty is not signed and even when it is signed the amount of the indemnity is not fixed. When the size of the indemity is determined, your share in it must be fixed. You are in the position of a man whose house has burned down and the insurance has not yet been adjusted.

Many of the establishments were old and out of date. Many were poorly located for the work they had to do. New combinations of capital are being made and the whole business structure is undergoing changes. Some of the steel and iron manufacturers whose plants were entirely destroyed will produce an entirely different product when they are rehabilitated. The reconstitution of the destroyed industries of France and Belgium means more than mere mechanical reconstruction and is not to be accomplished in a year. It will take many years, for if all other factors were favorable, shortage of labor alone would cause the work to extend over a period of years.

The French government has taken a very strong stand against the importation of commodities to France. After obtaining an order for equipment of any kind, it is necessary to obtain an importation license, and in most cases it is almost impossible to obtain such a license, even with the active help of the French purchaser. This policy has been carried to a great extreme and it has sometimes been impossible for Frenchmen to import goods that could not be duplicated in France. An article which had a French substitute could not be purchased elsewhere. This policy has been carried so far that it has become a burden to Frenchmen who need foreign goods in order to assist them to get back into production quickly, and I found widespread dissatisfaction

with the present government on this account. It was freely said that there would be a change by the government as soon as the peace treaties were ratified and that the way would be made easier for the importation of foreign goods.

Although there seems to be general dissatisfaction with the restrictions placed on foreign goods, the French people do not intend to see their country exploited by foreigners. They feel that economically France has lost the war. They fear German competition. The French pride themselves on their ability to do good construction work and they expect to rebuild their own works. They do not intend to let Americans or Englishmen exploit them at this time.

I often hear Americans express the opinion that, as a result of the prejudice engendered by the war, business that was formerly in German hands would fall into the hands of the Allies. I have also heard the opinion expressed that the French and the Belgians would not do business with Germany. I think there are individuals in these countries who will refuse to deal with a German, but I think they do not represent a very large percentage of the business men. French and Belgian business men very frankly say that they will be forced to do business with Germany. At the time we were in Belgium the rate of exchange was not so strongly against them as it is now, but there was at that time considerable bitterness on the part of the people, directed particularly against England, because many of them felt that English statesmen, who had so often publicly stated that Belgium should be reimbursed for her losses, had not kept faith with her.

When an American or an English salesman demands spot cash payment for goods which Belgium needs, it angers the prospective customer, especially when the buying power of their money has depreciated to such a great extent. The natural consequence is that Belgium will turn to Germany for the goods she needs if she can purchase them on better terms. The French will do likewise. It would be economic suicide if these people did not buy in the best market. Their burden is intolerable at best. Their factories must be reconstructed at a time when labor and material are commanding prices higher than ever before; and if they are ever to compete in the markets of the world they are

justified in purchasing in the cheapest market, even if that market be in the enemy's country.

The normal rate of exchange between France and the United States makes one franc equal to 19.3 cents. This week the franc is quoted as low as 11.5 cents. This means that for every dollar's worth of equipment purchased in this country the French must pay the equivalent of $1.68 in French money. This is a problem which our financiers must solve if we are to have a large share in furnishing the material so much needed in France and Belgium.

SOME COMPARISONS OF AMERICAN AND EUROPEAN BY-PRODUCT COKE-OVEN PRACTICE

One of the main purposes of our trip was to see something of the progress that has been made in the by-product coke industry on the other side of the water. We have built a great many by-product coke-ovens in this country during the past five years but, due to the war, we have been practically cut off from a knowledge of the developments which have occurred in Europe during that period. When I was asked to present a paper I consented after considerable hesitation. It would be a much easier task if I could report some vital respects in which European practice, as I saw it, was superior to ours; and I am sure my paper would be much more acceptable to those engaged in this industry, if, as a result of our trip, I could point out more ways of improving American methods. I have returned to America with the positive conviction that in the most vital things our construction and operation of by-product coke plants in this country is superior.

I have elected to discuss this question under three general headings:

Architecture and Construction. I was very much impressed with the fine architecture and very careful attention to detail in some of the new by-product coke plants under construction and nearing completion. In fact, it seemed to me that in some cases an attempt at beauty in architecture had been allowed to play too great a part in determining the arrangement of the apparatus. The very careful design of the piping and the smaller details was

striking. Everything about the work indicated great care and attention to detail. I believe that we in this country have in the past not paid sufficient attention to beauty in design and refinement in detail, and I am of the opinion that considerable improvement can be made in this regard without appreciably affecting the cost of construction.

The construction work was beautifully finished. The floors were more carefully laid than is usual in our works, and in this I am not referring to coke plant construction only. Except in special cases our industrial plants are built strong and rugged, but they have usually been rough in finish. I am of the opinion that a little more finish will reduce operating costs. It is pretty generally agreed that dirt breeds inefficiency. A hard, smooth, concrete floor, properly finished, can be swept clean; while a rough, porous one, cannot. Oil and tar stains can be cleaned from tile, but they cannot be removed from concrete. I agree that these things can be carried too far, but I have not yet seen a by-product coke plant that was ideally designed and constructed in these respects.

Mechanical Equipment and Plant Lay-Out. American practice in this regard is distinctly superior. Our equipment is more rugged and more reliable. The new plants which we visited in Europe, although better in every way than those built before the war, are not comparable with American practice of the past few years.

The multiplicity of units to handle a small tonnage is very noticeable. We visited a plant in France which will carbonize about 2400 tons of coal a day. It was composed of six batteries of ovens arranged, not with a common center-line, as is our custom, but each battery separate, with parallel center-lines and individual coal-bins. This necessitated a pusher machine for each battery, two coal charging cars for each battery—the gas collecting main being in the center of the battery—and extensive duplication of coal- and coke-handling equipment. When one considers that the shortest possible coking time in this plant was 24 hours and the normal time 30 hours, giving a pushing schedule of 35 to 45 minutes for each machine, it is evident that this arrangement is the cause of a great waste of

equipment and labor. A modern American plant of this capacity would be equipped with one coal-bin, instead of six; two combined pushers and levelers in operation, instead of six; one coal charging car in operation, instead of 12. It would contain two batteries of about 60 ovens, instead of six of 42. In England, we visited a plant similarly arranged constructed during the past few years by another builder. Of course, not all the plants were arranged in this way. We visited a new plant in Wales which was just ready to be put into operation. The details were carefully thought out, and the construction work beautifully executed. The nominal capacity is about 1200 tons of coal a day with a coking time of about 26 hours. For such a small capacity, we were impressed with the excessive amount of equipment provided. The plant is composed of 120 ovens, split up into four batteries of 30 ovens each, arranged in one line. With the larger ovens and the shorter coking time obtained in this country, such a capacity would be conservatively obtained with 70 ovens which would be constructed in one or perhaps two batteries.

There is one point I wish to emphasize, which is true of the by-product coke-oven plants in all the countries visited. The cost of these plants, assuming the same unit prices for labor and material, must be considerably higher per ton of coal carbonized than similar plants as designed in this country. If for no other reason, the long coking time which reduces the capacity of European ovens, as compared with American ovens of the same volumetric capacity, must add greatly to the cost of construction.

I was very much interested in noting the extreme care with which coal is handled, particularly in some of the collieries in Belgium. The mining of bituminous coal in France and Belgium is very different from the mining operations with which we are familiar. The mines are very deep, many of them over 3000 feet below the surface. The coal is relatively very much more costly at the pit mouth, and, as a consequence, it is mined and handled much more carefully than in America. Practically all the coal is carefully screened and washed. The larger sizes are sold at higher prices for special purposes, and only the very fine material is used for coking. The slurry and fine coal are also made into briquets, which are used quite extensively for locomotive

firing on the railroads. We were told that an ordinary guarantee for a coal washing plant was two per cent. ash with a loss of about two per cent. of good coal in the washery refuse. The ash content before washing was in some cases, as high as 15 per cent. or more, which would make the coal useless for coking purposes without washing. In the plants we visited, the washing water was used over and over again, thereby avoiding the contamination of streams with waste water. Draining bins seemed to be the common method of drying the coal.

The coal washing plants in Europe impressed the writer very favorably. They were clean to a remarkable extent. In fact, it seems to me that European engineers have progressed much further in the art of washing coal than in the art of coking it.

We have much to learn from Europe along the lines of conservation. As our rich gas coals and coking coals become scarce, and therefore more valuable; as our mining costs increase, due to the increased cost of labor; as freight rates increase, making it unprofitable to ship fuel with high ash content; and as the consumer realizes the economies which may be effected by the use of a cleaner and more uniform fuel, we will be forced to adopt European methods of conserving coal.

Most of the coal is crushed in jaw or roll crushers and pulverized in disintegrators. These disintegrators work very well for small capacities. We did not see any hammer mills such as we use so extensively in this country. Where coal is mixed it does not seem to be so carefully mixed as is our practice. Belt conveyors are used for handling coal, but not so extensively as in American coke plants. Perhaps the development of the apparatus used in this country for the handling of coal and coke is largely the result of the large capacities of most of our plants as compared with those of Europe. The largest plant we visited carbonized about 2400 tons of coal, while a plant of 1200 tons capacity is considered a fairly large one. It would be practically impossible to handle the tonnages to which we are accustomed, with the ovens and the apparatus in use in Europe. The general practice in Europe is to push the coke out of the oven, through a coke guide composed of perforated pipes, on to an inclined wharf extending the full length of the battery. From this wharf it is

either forked by hand into cars—the forking operation taking the place of mechanical screening—or it is fed through gates, extending the full length of the wharf, to a steel pan conveyor which conveys it to a screening station. Quenching immediately in front of the oven was abandoned several years ago in this country, but we did not see a plant in Europe with a central quenching station.

It is not necessary to point out to American operators the disadvantages of this system. Quenching is a dirty operation, at best; and with the system in use in Europe it is not possible to provide for conveying the steam away from the ovens and the immediate vicinity, or to dispose properly of the waste water and its entrained coke dust. In cold weather this method of quenching is especially objectionable. A central station is much cleaner and gives greater uniformity of quenching. The continuous wharf of massive, arched concrete or brick construction, covered with cast-iron plates and equipped with feeder gates the full length of the battery, is very expensive; and steel pan conveyors are not suitable for handling coke, due to the abrasive action of the coke on their many moving parts.

It seems to the writer that this choice of coke-handling equipment is largely responsible for the extensive duplication in the equipment used. One of the plants previously referred to, which we visited, had a capacity of approximately 1800 tons of coke and was equipped with three steel pan conveyors, each conveyor located between and serving two batteries of ovens and delivering coke to individual screening stations. The first cost, maintenance, and labor cost of such appliances must be excessive. For the same service we would employ a single wharf instead of six, and one conveyor and central screening station instead of three.

Some of the most modern plants abroad, are equipped with a large coke screening and loading machine, which travels on rails in front of the ovens. The quenching is done directly in front of the oven—while the coke passes through the coke guide—by means of a water spray formed by forcing water through the perforated pipes of which the coke guide is constructed. The coke then falls on an inclined wharf which is full length of the battery, and a large percentage of the quenching is done by hand on this wharf. Gates are provided at the lower end of the wharf

throughout its entire length to discharge the coke to a large steel bucket elevator which is mounted on the machine and which delivers the coke to a bar screen which terminates in a chute to the cars. The breeze and small coke pass through the screen into cars which are placed directly under the machine. Such a machine could not easily be supplied where several sizes of coke are to be produced. It is an improvement over the pan conveyors which I have just described, because it makes it possible to handle the coke with machinery and construct several batteries in one line and thus economize in pushers, coal-bins and charging cars. It does not, however, eliminate the objectionable feature of quenching in front of the ovens.

In Belgium, coke-handling apparatus has seldom been installed. When coke can be forked by hand from a wharf into cars for an equivalent of four cents a ton (which was the cost before the war) it is hardly to be expected that mechanical equipment will be installed to do the work. Such labor rates are a thing of the past and mechanical equipment will undoubtedly be required in the future.

There is no radical difference between the by-product apparatus of the several types in common use in Europe and similar types in this country. In this department of the work, as in the others, no effort seems to have been made in the newer plants to skimp the apparatus either in quantity or quality.

Coking Time. In our visits to coke plants the question most often asked by managers and superintendents (second only to inquiry regarding our labor situation) had reference to the short coking time prevailing in America. In England, France, and Belgium, designers and operators of by-product coke-ovens cannot understand why the normal coking time of American ovens averages only about 60 per cent. of the normal coking time for ovens of the same average width in Europe. We have found it very difficult to explain such a great difference, to European engineers and operators, as being due to improved methods of construction and operation; but I am convinced that this great difference can be accounted for in no other way. Briefly, and without going into technical detail, the following are the most important explanations:

It is the practice in this country to use silica material in by-product coke-oven construction. Some English firms were experimenting with silica walls in old batteries that were being repaired, but this will hardly be a fair test. I think there is not a single battery of ovens in England, France, or Belgium constructed of silica brick—the material used ranging from what we would term fire-clay up to quartzite, with a maximum silica content of about 85 per cent. The fusing temperature of silica brick is higher than the fusing temperature of brick such as they use; but more important still, the softening point under load is 500 or 600 degrees F. higher for silica brick than for fire-clay or quartzite brick. Temperatures as high as 2700 to 2750 degrees F., which we maintain in the heating flues without injury to the brickwork, cannot be obtained with material of lower silica and higher alumina content. For this reason, there is much greater safety in operating a battery of ovens composed of silica material. The walls of the heating flues may be at the fluxing temperature before they will fail, but a clay brick wall will soften and deform under its own weight before its fluxing temperature is reached. Silica material also has greater conductivity, which, added to the much higher temperature head available, makes it possible to transmit the requisite heat through the walls and into the coal in a much shorter space of time. Silica brick expands to a greater extent than fire-clay brick, but it has the convenient quality of continuous expansion at all temperatures up to its softening point. Fire-clay brick, however, expands up to about 2000 degrees F. and then contracts. It is practically impossible to keep coke-oven construction gas tight under such conditions. As expansion takes place, the tie-rods and buck-stays can be loosened, but tie-rods and buck-stays will not close the joints opened up by contracting brickwork.

The next consideration—and of equal if not greater importance—is uniformity of operation. Coking operations are much more uniform in this country. A good operator here will fix the coking time to meet the coke or gas requirements within the limits of the capacity of the plant and insist on absolute regularity of pushing. The men responsible for the heating must see that the coke is ready to be pushed at the scheduled time.

Such regularity of operation is not obtained in Europe. Either the plants which we visited were not properly operated, or their design and construction are such that they could not be properly heated. The heats were generally not uniform.

Gas pressure regulation in the ovens does not receive the careful attention that we give this feature. We visited a new plant in which gas exhausters were to be driven by a motor through a line-shaft with no means of regulation except by operating, by hand, a gate-valve in a by-pass line around the exhauster. Nowhere did we see any serious attempt to control the gas pressure in the oven chamber. With leaking walls and wide ranges of pressure within the ovens it is impossible to obtain good heating. It is not putting the case too strongly to say that we did not visit a plant in which the gas was properly burned and the ovens uniformly heated.

The reliability of the mechanical equipment is a matter of great importance in the maintenance of uniformity of operation. Some of the new plants in Europe show marked improvement in this respect.

It seems to be the opinion among Europeans that the great difference in speed of coking in American ovens is due to the nature of the coal or to its moisture content. I have inquired carefully into this matter and our experts tell me that this is not true. We have a wider range of coal in this country than can be found in Europe, possessing all the characteristics that tend to lengthen the coking time, and in some cases to a more marked degree than in European coals. High moisture content has some effect on the coking time, but in 16 hours we have coked coal with 15 per cent. moisture—so wet that the water ran out of the oven doors—in an oven with an average width of over 19 inches. A difference in the quality of the coal may affect the coking time, but cannot be charged with a difference of 10 to 14 hours. We did not visit a plant that was pushing coke in less than 30 hours and the maximum practical speed in the newest plants is 24 hours.

The only explanation for the greater speed of American ovens is to be found in the details of design, the materials used in the construction, and the more uniform and scientific operation.

DISCUSSION

Mr. E. D. Leland, *Chairman*:* We have all been interested and instructed by this first hand information brought to us by Mr. Thompson. It has covered a wide range and I am quite sure he is willing to supplement it if any of our members are desirous of asking questions. The subject is now open for general discussion.

Would you mind telling us, Mr. Thompson, why it is they do not use silica brick abroad?

Mr. John I. Thompson: I did not thoroughly investigate silica brick abroad, but I think they are obtainable. They have many open-hearth furnaces built of silica brick, and silica material that is satisfactory in an open-hearth will be suitable for coke-oven work. In France they are making silica brick for their furnaces. I could not get a good reason from any coke-oven builder or operator as to why they did not use silica brick. Silica brick were not used in the early development of coke-ovens and I should not be surprised if the reason for the continued use of clay and quartzite brick is due largely to prejudice or lack of experience with this material. Furthermore, I do not believe they thoroughly understand the method of heating an oven with silica brick and of taking care of the excessive expansion.

Mr. C. W. Littler:† I would like to ask the speaker a few questions about European practice. I am very much surprised to hear that the by-product oven in Europe is in design and operation far behind our American ovens. Our designs are really based on European patents. The regenerative application is based on the Siemens principle developed by Mr. Otto and later improved by H. Koppers especially as to control of heating and conservation of heat.

Having much longer coking time over there, I wonder whether the blast-furnace specifications for coke have anything to do with it. The blast-furnace people in this country were for

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†Chief Engineer, Clairton By-Product Coke Works, Clairton, Pa.

a long time opposed to by-product coke, especially as to size and structure of this coke. With regard to the arrangement with six separate batteries, each having a separate screening arrangement, I wonder whether their specifications are still so rigid as to confine the product to a very slight range in sulphur content, each battery making a certain coke depending on the coal charged.

Europe, much poorer in natural resources, was compelled to develop the by-product industry much earlier than we and should be further advanced than this country. The developments here during the last five years have been surprising and I wonder why Europe has not kept up the development with us.

MR. JOHN I. THOMPSON: Regarding the specifications for coke in blast-furnace practice, short coking time does decrease the size of the coke. Practically all the coke I saw pushed in France and Belgium was very large and very blocky. I was told that blast-furnace operators would not accept the small coke we sometimes make in this country; but it is a fact—which will be corroborated by any blast-furnace operator present who has used by-product coke—that by-product coke, due to its uniformity and perhaps for other reasons, does reduce the fuel consumption and quite often increases the iron production in blast-furnaces. There has been a prejudice in this country against the small coke produced in some of the by-product ovens, but I think that prejudice is gone. In fact, some operators prefer the smaller coke, provided it is uniform.

I was interested to find that there are not many coke-ovens situated at the blast-furnaces in Belgium. When the ovens are located at a distance from the blast-furnace, and under separate management, it gives the blast-furnace operator an opportunity to demand almost anything, because he is buying his coke; while, if the coking operation is within the plant itself, there is more co-operation and the coke best suited to the furnace operation can be made. The coke-ovens in Belgium are largely located at the mines, and for that reason they are small in capacity and the coke is sold.

Regarding the matter of coking time in Europe, it is interesting to note that the first Koppers plant that was built in Amer-

ica pushed coke in a shorter time than any Koppers oven that had been constructed in Europe; and that is true not only of Koppers ovens but of other types, with the exception of some very old plants. I think our method of operation is more scientific and they have simply allowed us to step ahead of them in this regard.

MR. J. J. WILSON:* The speaker has told us about Belgium, France, and England. I would like to ask him about German and Scandinavian practice Is what he has said regarding design of plant and coking time also true of German practice?

MR. JOHN I. THOMPSON: I did not get an opportunity to go into Germany because the peace treaty had not been signed. I had a pass that allowed me to go anywhere in the occupied territory, but I was so tired of fighting about the food and transportation and other inconveniences, and I was so busy with other things, that I did not avail myself of the opportunity to visit that portion of Germany occupied by the Allied armies.

I saw a plant in Stockholm that was constructed during the war, by Koppers of Germany, and the battery looked very good. They were testing silica brick in this plant. Half of the plant was silica material and half was clay. The ovens were heated with producer gas from producers fired with coke, and were operating very satisfactorily, but they were not getting the results that we are obtaining. The plant was short of coal, and at the time I was there they were unloading coal which had been shipped from Fairmont, W. Va. I think the cost was about $27 a ton. During the war these people used wood in the retorts to make gas for the city of Stockholm.

But even in Germany before the war, although the German engineers were familiar with what we were doing and had visited America a number of times, they did not get as good results as in America. I tried to get an explanation of our superiority, and the reasons given in the paper are my conclusions. The ovens that are constructed in Europe are not fundamentally different from the ovens of the same type that we build, but they are very different in the details of design and method of operation.

*National Tube Co., McKeesport, Pa.

Mr. A. C. Fieldner:* I should like to ask whether there are any striking differences in by-product recovery practice in the United States and that which came to your attention in Europe, with special reference to the kind of by-products they recover and the utilization of tar.

Mr. John I. Thompson: There is no radical difference in that regard. As to the quantity of by-products, that is almost an impossibility to determine on a short visit to a plant. In the first place, the coal largely determines the quantity of the by-products, and the oven itself and the way in which it is operated are large factors. Our experts tell me that it is not true that greater by-product yields are obtained in Europe than here.

As to the by-products recovered, they are the same. There is a tendency in Europe to locate tar distillation plants at the coke plants. The tar business in this country is largely in the hands of a few large companies, which take the tar from the coke-ovens and distil it. Distillation is often done in the coke-oven plants in Europe. Otherwise I do not think there is any radical difference.

My impression of European operators is that they are excellent chemists and that they know the fundamentals of the business, but if their ovens are leaking air and the heating conditions are not right the maximum by-product yields cannot be recovered, no matter what system of recovery they use.

Mr. James D. Miller:† I would like to ask if Mr. Thompson met with any information on coking coal under reduced pressure. Experiments have been conducted in Europe by a Frenchman and a Swiss along that line. Is the method likely to be of commercial importance?

Mr. John I. Thompson: I am not familiar with that and I did not hear or see anything of it while I was abroad.

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NICKEL-CHROMIUM ALLOYS

By W. A. Gatward*

OUTLINE

Introduction
Early Development
Present Status of the Industry
Properties of Alloys Available for Resistance Purposes
Requisites of Good Material for Heating Elements
Peculiar Properties of Nickel-Chromium Alloys
Uses to Which Nickel-Chromium is Adapted
Application of Nickel-Chromium to Pyrometry

INTRODUCTION

In writing this paper the author realizes that it is impossible to cover the subject completely in one evening. The literature on the subject is very meager at present but nickel-chromium alloys have taken such an important place in modern industry and domestic life that eventually there will be produced a well rounded literature on this broad and ever developing subject. The object of this paper is to bring the question up for future consideration. A discussion of a few of the problems which are of outstanding importance will lead to discussion of other points which are not so well known and it is hoped that these discussions and future papers will bring about a better understanding of the problems of the manufacturer and the user of the alloy.

EARLY DEVELOPMENT

The peculiar properties of nickel-chromium alloys, which make them especially suitable as resistance units for heating devices, were discovered by A. L. Marsh in 1905. The early stages of research consisted of several hundred experiments on different combinations of nickel and chromium, as well as combinations including these two metals and one or more additional metals. Conclusions arrived at after years of work are that the desirable properties are due to the peculiar effect of chromium. The discovery that the alloys of nickel and chromium had desirable prop-

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erties, was not the end of the problem; it was necessary to develop alloys that had all the good properties and which at the same time could be cast, rolled, and drawn into suitable form. There is no doubt, even now, that the manufacture of nickel-chromium is one of the most difficult problems in metallurgy. It was even more so at first, due to lack of experience. Both nickel and chromium melt at high temperatures and nickel is a solvent for carbon. Furthermore, chromium at the melting point is very easily oxidized. Hence the alloy in the early days was subject to widely varying percentages of carbon which greatly affected its rolling, and the castings were very much subject to the effects of included and dissolved oxids. Proper methods of deoxidation had to be developed. There were many months when it was impossible to reduce any metal to wire form. Bars were very small until recent years and the smaller the bars the more subject they were to varying properties. Another difficulty was the variation in the composition of the raw materials. There is no difficulty now in obtaining plenty of nickel and chromium but the fact of the matter is that the nickel-chromium alloy has been partly responsible for the development of the pure nickel and pure chromium supply. During the development of the alloys the raw materials were not so dependable.

With all respect to science, it is true that the nickel-chromium industry since the very beginning has been free from hair-splitting scientific calculations. This is inherently true of research in alloys, and the nickel-chromium industry has shown it very clearly. This does not mean that brains are not necessary; neither does it mean that the work is not done in a scientific way—nothing is farther from the truth—but there is not a single step in the development or in the process of manufacture that was not worked out entirely by experiment, and at no time has it been possible even to guess what would be the properties of untried alloys or what would be the effect of any of the many variations in the processes of production. The problem of the producers has been to observe past results, to determine what things to try and then to make the experiments and select the good from the bad. The slightest change in the process is apt to affect results at some later stage, hence there must be careful control at all times.

PRESENT STATUS OF THE INDUSTRY

The present standing of the nickel-chromium industry is probably higher than is generally known. Since 1906, about two thousand tons of nickel-chromium have been used in the manufacture of heating devices. In considering the importance of the alloy industry one must include the allied industries and these include the production of the raw materials—nickel and chromium—and the manufacture of various sorts of heating devices.

The fact that nickel-chromium is the only commercial substitute for platinum as a heat resisting material, should speak for itself. The many devices in use to-day, both in domestic and industrial work, are only a few stages removed from luxuries. Three factors were active in changing these devices from luxuries to necessities. They were as follows: (1) cost of electrical current, (2) development of nickel-chromium heating elements, (3) large-scale production of the devices. The first item, cost of current, was a stumbling block for a long time but central stations are now seeing the advantages of the "off-peak" load and are giving rates which are entirely satisfactory. The second item is the real solution to the problem as the first and third items were inevitable once the second item had been taken care of. A device is or is not a luxury depending on whether or not it is durable. In other words, a toast stove which costs $5 and lasts only a month is a luxury, while a toast stove which costs $5 and lasts five years is not a luxury.

It would be a broad statement to say that had Mr. Marsh not developed his alloy it would not have been developed eventually by some one else, but it is a fact that this alloy is indirectly responsible for the present standing of the nickel and pure chromium business and for the entire field of domestic and industrial heating.

The third point mentioned above—large-scale production—has been important in making possible the general use of domestic heating devices. One can purchase for very reasonable prices devices which have real quality, both in material and workmanship, a condition due entirely to large-scale production and merchandising.

PROPERTIES OF ALLOYS AVAILABLE FOR RESISTANCE PURPOSES

Before going into the subject of available materials and their properties I would like to clear up an idea which is very prevalent. The term "nickel-chromium alloys," as generally used, includes alloys of nickel and chromium and also alloys of nickel-chromium with manganese, aluminum, iron, or silicon in varying percentages. An alloy used considerably and known as "Nichrome" is one of these alloys and it is generally thought that it is the only alloy available and that it is made by the Hoskins Manufacturing Company, of Detroit, as well as by the Driver-Harris Company, of Harrison, N. J. Such is not the case. "Nichrome" is an alloy of 65 per cent. Ni., 24 per cent. Fe. and 11 per cent. Cr., and is manufactured by the Driver-Harris Company under the name of "Nichrome," while the same alloy is made by the Hoskins Manufacturing Company, under the trade name of "Chromel C."

The following table gives a list of the available alloys of nickel-chromium and modifications of the pure alloy. Column 1 gives the trade name, column 2 the name of the manufacturer, column 3 the composition, column 4 the ohms per circular mil foot, column 5 the published temperature coefficient, and column 6 the working range. The various items are tabulated for comparison:

Name	Maker	Published composition	Ohms per circular mil foot	Average coefficient per degree F.	Temperature range degrees F.
"Chromel A"	Hoskins Mfg. Co.	80% Ni., 20% Cr.	620	0.00006	2000
"Chromel B"	Hoskins Mfg. Co.	85% Ni., 15% Cr.	535	0.00006	2000
"Rayo"	Electrical Alloy Co.	85% Ni., 15% Cr.	575	0.0001	2000
"Kromore"	Driver-Harris Co.	85% Ni., 15% Cr.	570	0.0001	2000
"Chromel C"	Hoskins Mfg. Co.	65% Ni. 24% Fe., 11% Cr.	650	0.0001	1000
"Nichrome"	Driver-Harris Co.	65% Ni. 24% Fe., 11% Cr.	600	0.00024	1000
"Calido"	Electrical Alloy Co.	65% Ni. 24% Fe., 11% Cr.	600	0.0002	1000
Copper	....	....	9.4	0.00238	212
Aluminum	....	....	17.3	0.00235	212
Iron	....	....	58.0	0.00347	212
Nickel	....	....	74.0	0.0034	1800

A study of this table will show the reader that he has a rather wide range of physical properties from which to choose. All are sufficiently high in resistance to be classed as heating-element material. The only limit for resistance is that the material shall have sufficient resistance so that a wire, which can be placed in a unit of convenient size, shall at the same time be large enough in cross-section so that the current it carries will not heat it beyond its safe temperature.

Both specific resistance and temperature coefficient are satisfactory. The important feature is resistance to oxidation at a high temperature. Results of years of experience and hundreds of life tests have proved that the alloy "Chromel A" is the most desirable alloy available. This durability is a hard thing to define and to specify but it can at least be said that at 1000 degrees C. this alloy has a life from 10 to 20 per cent. greater than for any other straight nickel-chromium alloy. At 800 degrees C. they are all very durable but as the temperature increases the life is shortened. The "A" grade at 1000 degrees C. is about twice as durable as the "C" grade for the same temperature. This factor of safety in "Chromel A" is very important in resisting the formation of hot spots.

REQUISITES OF GOOD MATERIALS FOR HEATING ELEMENTS

The requisites of a good material for heating elements are many. Some are purely physical and some rest on economic principles. The principal points are as follows: (1) High specific resistance, (2) Low temperature coefficient, (3) Reliable temperature coefficient, (4) Reliable composition, (5) Accurate size, (6) Reasonably long sections, (7) Proper spooling, (8) Durability at a temperature considerably above its operating temperature, (9) High conductivity of heat—a requirement which can not be perfectly attained, (10) Clean surface, (11) Smooth surface, (12) Uniform annealing, (13) Freedom from defects.

1. The specific resistance must be high. Any wire can be used, to a certain extent, as a heating unit. The trouble is that in using low resistance wire one must use either a small section or a considerable length. The device usually is such that there is a

limit to the length that can be used and of course the weight will also be greater for low resistance material. If a small section is used the length will be slight but the radiating surface will be small and in order for the wire to radiate the heat developed it will operate at an excessive temperature. If the specific resistance is high, a larger wire may be used and the wire will operate at a lower temperature.

2. The temperature coefficient of the material should be low. It is desirable that the current that flows when a device is first connected shall not be much greater than when the unit is heated but this is not the most important feature. The development of hot spots (which will be discussed later) is very much affected by the temperature coefficient. Another effect of high temperature coefficient is as follows. Imagine a heating unit wound around a muffle as generally used in electric laboratory furnaces. The heating unit is a continuous piece of wire. Suppose that the furnace is operating at 1800 degrees F. and we place on the floor a fire-clay brick. The fire-clay brick immediately banks up the flow of heat and the temperature of the wire under the brick rises. This is not a theory but a fact and the rise is very serious. As the wire under the brick gets hotter its resistance increases. Since the current is the same in all parts of the heating coil, the heat developed, I^2R, will be greater on the floor than on the sides and top. Of course this phenomenon is cumulative and is the actual cause of many burn-outs in industrial devices. The higher the temperature coefficient the more serious this will be.

3. The reliability of the temperature coefficient is very important to the manufacturer. In designing a device the wattage is determined first. Then the future devices that are built are supplied with a measured amount of "cold resistance." The temperature coefficient must be uniform or the devices will consume varying wattages at full load.

4. The durability of the heating unit depends absolutely on the composition and of course this must be carefully controlled. It has been found that the durability at high temperatures is reduced both by decrease of chromium and by the presence of iron.

5. The size must be very accurate. This is not so important as the resistance per foot but since one determines the other it

is desirable for the manufacturer of the wire to draw very carefully to size.

6. The length of the pieces of wire is important because of endage losses.

7. The spooling should be carefully done in order that the wire may be removed from the spool without tangling.

8. The limit of life of a normal heating unit is either oxidation to a point at which the heat developed is not sufficient, or the development of a hot spot with a subsequent burn-out. The latter point will be discussed in a separate paragraph. Any device is subject to abuse and the greater the factor of safety the more satisfactory will be the device. The unit should not only be durable at the temperature at which it is supposed to operate but it should be durable at a temperature very much above that at which it is rated.

9. It is desirable, but apparently impossible, to obtain a heating unit of high specific resistance and at the same time of high heat conductivity. In all cases, low electric conductivity and low thermal conductivity go hand in hand. The thermal conductivity of nickel-chromium alloys is about one-fourth that of copper. It is necessary that the heat developed at the very center of a wire be carried to the surface and there radiated. Low thermal conductivity, therefore, means that a wire is a little hotter at the center.

10. It is desirable that the wire have a perfectly clean surface so that it may be soldered and brazed easily. Not all nickel-chromium wire can be produced perfectly bright but the Hoskins Manufacturing Company is now producing most sizes with a perfectly clean surface.

11. Units are usually wound by hand and the wire should have a smooth surface.

12. The wire must be uniformly annealed so that when coiled it will stretch evenly.

13. The wire must be free from defects. A slight decrease in effective cross-section tends to cause the development of hot spots and subsequent burn-outs.

PECULIAR PROPERTIES OF NICKEL-CHROMIUM ALLOYS

Certain peculiar properties of nickel-chromium are responsible for its success. One of these is the tendency toward self protection against oxidation by the formation of a close clinging scale. Oxidation takes place immediately when the wire is heated but the scale that forms protects the wire from further oxidation and this scale clings to the surface very closely even on repeated heating and cooling. This property of course varies with the temperature; it is particularly noticeable in "Chromel A" at 1000 degrees C., is not so characteristic of "Chromel C" at 1000 degrees C., but is true of "Chromel C" at 800 degrees C. If coils of "Chromel A" and "Chromel C" are heated for some hours at 1000 degrees C., a little pile of brown powder will be found to have fallen from the "C" coil while the scale will be found to have clung close to the "A" sample. The formation of this refractory oxid may be further illustrated. A wire can be supported and heated by a current to a white heat and the wire will last for some seconds at a temperature considerably above the actual melting point of the alloy. When the wire finally burns out it will be found to consist of a tube, sometimes wrinkled. The core has melted and run out while the oxid remains. During the time the current was flowing the wire consisted of this oxid tube containing a thread of molten metal.

Another peculiarity is the resistance to the formation of hot spots. The tendency to their formation is normal for any wire. The peculiar properties which resist the formation of the hot spots in "Chromel" are the low temperature coefficient and resistance to oxidation on the surface of the hot spot. Assume for a moment a wire having a high temperature coefficient and one which easily oxidizes at a red heat. Assume also that it is carrying a current. There is very apt to be one little spot which is slightly higher in resistance than all other points along the wire. This spot soon reaches a slightly higher temperature. Now, since we assumed a high temperature coefficient, we will find that the hot spot develops a little higher resistance. This, in turn, causes a greater development of heat and the cumulative result is a very hot spot which either oxidizes away or actually melts. To counteract these effects we must have a wire with a low

temperature coefficient, which does not oxidize readily at high temperatures and which has a high melting point.

Another property of "Chromel" is its very dependable thermo-electric character. The millivoltage can be controlled perfectly and, since the alloy is highly resistant to oxidation, it is used with marked success as a thermo-couple element.

USES TO WHICH NICKEL-CHROMIUM IS ADAPTED

The uses to which nickel-chromium can be put are varied. Tabulated they are as follows:

Rheostats (low temperature).
Ovens (300 to 400 degrees F.).
Irons (700 to 900 degrees F.).
Cook stoves and grills (red heat).
Laboratory devices (1800 to 2000 degrees F.).
Heat treating furnaces (1600 degrees F.).
Heat resisting devices, such as gauze, triangles and tongs.
Castings to support apparatus in heated regions.
Protecting tubes for thermo-couples.
Carbonizing boxes.
Branding irons.
Heated rolls.
Wire and extension wire for thermo-couples.

There are hundreds of special uses for the alloy some of which are known and many of which are yet to be discovered. Nearly every day some new application is found and there would be many more if the wants of the trade could be more generally known.

APPLICATION OF NICKEL-CHROMIUM TO PYROMETRY

The application of nickel-chromium to pyrometry deserves a little more attention.

Base-metal couples are rapidly replacing platinum couples for temperatures up to 2300 degrees F. The same statement may be made for this subject as for industrial and domestic heating. The general use of pyrometers to-day, and the great advantage all over the country due to their use, was made possible by the development of the nickel-chromium element for the base-metal

couples. In the first place, it is certain that the development of pyrometry would never have been made with platinum couples as the foundation. In the second place, there is no pair of couple elements except "Chromel-alumel" which would have given to the public the confidence in the base-metal couples. The secret of success lay in the development of a good positive element. The negative element is easily taken care of with an alloy consisting mostly of nickel. The positive element is made of about 90 per cent. nickel and 10 per cent. chromium. Both the positive and the negative are very resistant to oxidation, both have high melting points and by proper care they can be produced in pairs to give a guaranteed millivoltage. When used under oxidizing conditions and protected from reducing gases, the temperature-millivolt relation is remarkably constant at all immersions. It is fortunate that the "Chromel" alloys should have so many allied properties all useful in the production and measurement of heat. This alloy cast as a protecting tube has the usual property of resisting oxidation and has a very high melting point. It is also impervious to carbon monoxid gas and that is one of its important properties as a protecting tube. Iron tubes are not impervious to carbon monoxid gas at temperatures above red heat. "Chromel-alumel" couples are contaminated by contact with gas if iron tubes are used for protection where carbon monoxid gas is present. On the other hand, they are perfectly protected by "Chromel" tubes at all temperatures up to the temperature of failure.

To secure the best results from "Chromel-alumel" couples they should be installed in a "Chromel" protecting tube and the tube should be rigidly supported in the furnace wall. The diameter of the tube should be such that a check couple can be inserted without disturbing the couple. The couple is rather fragile when hot although it may be bent to any desired shape while cold. Couples installed as described above have been used considerably more than a year and have been checked frequently and found to maintain their original millivoltage. The secret of success with these couples is proper protection, which means using a strictly oxidizing atmosphere at all times.

DISCUSSION

Mr. C. E. Skinner:* I would like to ask if a method has been found for getting an accelerated test for oxidation. Users are, of course, confronted by the statements of the different makers of nickel-chromium wires as to the merits of their respective products, and it is desirable that information be made available in less time than will be taken for a good nickel-chromium wire to disintegrate.

I would like a little idea of just how aging tests are carried on. I assume from the statement in the paper that the standard test is made at somewhere about 800 degrees C.

I would like also to ask the effect of fluxes on the heating element. In asking this, I am thinking of a case where we had a Hoskins furnace of the hairpin type where we generated some gases which penetrated the muffle, and the furnace lasted only a very short time. My attention was also called to certain coverings put in contact with nickel-chromium wire, which may cause difficulty from fluxing action at a relatively low temperature. I would like to ask what precautions should be taken against some of these troubles.

I should like to ask also how closely this thermo-couple can be matched—that is, what is the percentage of error in couples that may be sent out as a commercial proposition?

Mr. P. H. Brace:† With regard to castings, what percentage of castings can be made gas-tight as regards seams, cold-shuts, etc.?

In connection with heat treating, "Nichrome" pots are often used to contain baths of molten lead. In some cases tin would be more desirable. Have you had any experience with the effect of molten tin at high temperatures on "Nichrome" castings?

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†Engineer, Research Division, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

It has come to me in a roundabout way that the Driver-Harris Company is developing an alloy containing 30 per cent. of chromium. Do you know anything of this?

What is the technique of soldering, tinning, and brazing "Nichrome?"

MR. W. I. SIVITZ:* I would like to ask the speaker's opinion regarding the following practice. It is very often necessary to determine temperatures of metals in the molten state. Under some conditions, iron tubes as a protection to the couple would not do, as there exists the possibility of the protecting tube dissolving in the liquid medium and thus making it impure. The custom is to use graphite, and the use of graphite tubes under these conditions, it seems to me, would be more serious than iron because graphite is more permeable to gases than iron is.

DR. JOHN S. UNGER, *Chairman*:† I would like to ask what is the largest size they have made these nickel-chrome castings. For instance, what sizes have they made boxes to be used in case hardening?

I would also like to know if they have ever made bricks of nickel-chrome alloys. I have in mind particularly some cases, such as the lining in the top of a blast-furnace, where the temperature is comparatively low, and in order to resist the abrasion of the stock falling off the bell, a common practice is to insert a number of cast-iron brick. These brick last fairly well. Has anything been done towards the use of nickel-chrome brick for such purposes?

Have nickel-chrome brick ever been used in furnace regenerators, or checkers, as we call them, for low-temperature work?

I would like to know something about the approximate cost per pound of these alloys when used in a large way—not as wire or heating elements, but as castings or rolled or forged products. Is the user of these nickel-chrome alloys responsible for their use, and must he obtain a license before using them?

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†Manager, Central Research Bureau, Carnegie Steel Co., Pittsburgh.

Have these alloys been used as vessels in laboratories to replace evaporating dishes or similar vessels used with the milder solvents in somewhat the same way as "Duriron," "Tantiron" and similar iron alloys?

Has the speaker observed whether the nickel in these alloys tends to combine with carbon monoxid and form nickel-carbon monoxid—a gas that is readily formed with pure nickel?

MR. S. H. KATZ:* The chairman has brought up a question which is of interest to me, and that is, the effect of solvents. There is a problem before us in which damp sugar is in contact with base metal for a period of weeks. Base metal is needed because of expense, and corrosion should be entirely eliminated. The best metal for our purpose at present appears to be nickel or "Monel metal." It is possible that nickel-chromium may have some advantages. If so, I should like to know of them.

MR. C. E. SKINNER: Do you make any attempt to scale the coiled wire during the test?

MR. W. A. GATWARD: Mr. Skinner's first question was about an accelerated life test on heating element wire. So far as I know there is no such test. An accelerated test does not give any idea of what a wire will do under service conditions. The wire must be heated by its own current—otherwise there would be no formation of hot spots. To heat a wire above its operating temperature, the normal current density must be exceeded, or else the wire must be insulated against heat losses. A few degrees at a high temperature is very important, especially if the temperature is up around the limit for the alloy.

We regularly test both straight and cooled wire at 800 and 1000 degrees C. We are in favor of the test of the coiled wire. The only objection is the long time required to complete a test.

There are two methods of determining the life of a unit. One is to run the wire at a constant temperature and the other is to run the unit at constant voltage. The unit is, of course, worthless when it will no longer do the work it was intended to do.

*Chemist, U. S. Bureau of Mines, Pittsburgh.

The length of time elapsing before a unit has fully depreciated is, of course, the true life of the unit for constant voltage devices. For electric furnaces with means of control, the life is determined by actual burn-out.

We do not "scale" the wire under test. We know that the protective, "close hanging scale" will form and protect the wire if the composition of the alloy is right. Therefore, we do not carry an intermittent "on-and-off" test. Intermittent conditions are harder on a wire than continuous use.

Mr. Skinner's question on the effect of fluxes on the hot wire is very important. When fusible material of almost any nature comes in contact with a hot wire the protective scale is destroyed and a burn-out soon follows. If a molten salt touches a coiled unit the current flows through the salt, short circuiting the wire, and this will always cause a burn-out. Fumes are also bad if they are present to any great extent. Cyanide and sulphur fumes are dangerous. Fumes should be carried away and salts should be kept away from the hot wire. Most muffle material will not keep fused salts away from the units on the floor of a furnace.

In answer to Mr. Skinner's question on the accuracy of matched alloys when "Chromel" is used, I can say that the pair of wires used in the couple is matched to within 10 degrees F., which is one-half of one per cent. of the full scale reading of 2000 degrees F.

Mr. Brace's question was regarding the soundness of castings. We have certain difficulties in castings, about the same as in iron, but by proper manipulation, castings can be made free from cold-shuts and seams. We require a little heavier section than for iron. The question of porosity has been overcome by proper deoxidation, clean pouring and the use of the right foundry methods.

I can not say how the alloy would serve as a container for molten tin. It gives very good service with molten lead and I believe it would be satisfactory for tin. The use of the alloy for these purposes is very much a question of economy and the first cost of the alloy sometimes causes people to pass it by when

it would be economical in the long run. Mr. Brace spoke also of an alloy of nickel-chromium containing 30 per cent. chromium. It would be very hard and brittle and there would be a great deal of trouble in making it.

Mr. P. H. Brace: We ran into the trouble, all right.

Mr. W. A. Gatward: The alloy can be made up to 50 per cent. chromium but can not be rolled or drawn. Its only application would be for castings. It can be welded by the use of feldspar and an oxy-actylene flame or an electric arc. We use the former. The wires can be tinned, soldered, and brazed, but the surfaces must be kept clean. Usually it requires a little practice.

Mr. Sivitz asked about the use of graphite protecting tubes for "Chromel" couples. The graphite should be used as an outer protection, only, and a gas-tight tube should also be used. This is true also of carborundum tubes or "Silfrax." The gas given off by the tube has a bad effect on the couple. For some metals —aluminum, brass, bronzes, and copper—we have an alloy called "Chromon" which is being used intermittently without contaminating the bath, and with great success in the production of good brass castings.

Dr. Unger's first question was on the size of castings that can be made. I have seen nickel-chromium castings that weigh a ton and are about 15 feet long.

Dr. John S. Unger, *Chairman*: What is the cross section?

Mr. W. A. Gatward: About one inch in thickness. Carbonizing boxes can be made in any required size, say three or four feet long. Tests on iron-nickel-chromium castings for carbonizing have been pretty well established. The tests for pure nickel-chromium are very promising but run into such a long time that we do not know yet just what the commercial standing is going to be. The material is wonderfully free from warping, which is a serious trouble with steel boxes.

We have never gone into the question of making bricks to withstand both temperatures and erosion. It is purely a question

of cost, and would be pretty expensive. I should think the big saving would be in reducing the cost of frequent replacing of the iron bricks.

Dr. John S. Unger, *Chairman*: Owing to difficulty of replacement, and the fact that ordinary fire-clay brick will wear away under mechanical abuse, we put in a metallic brick which does not wear away quickly. At the temperatures we use, most metals will scale. I think nickel-chromium would not scale and would still have the essential quality of resisting abrasion.

Mr. W. A. Gatward: The cast alloy could also be used for checkerwork bricks and they would not fill up the air spaces with scale. This work also would be expensive. The approximate cost of castings of heavy cross-section of 80–20 alloy is $1.50 per pound.

The alloy has not been used for evaporating dishes because there are pretty good dishes which are cheaper. We have used it to boil nitric and hydrochloric acid in and the only reagent that will put it into solution is *aqua regia*.

The question of combination of carbon with nickel, I can not answer. I do not know what the effect would be.

Dr. John S. Unger, *Chairman*: The combination takes place at a comparatively low temperature. When carbon monoxid is passed over nickel, it forms nickel-carbon monoxid, and, as the temperature is raised, it deposits metallic nickel in the form of nickel globules. The Mond process of nickel recovery is based on that reaction. I wondered whether the chromium in these alloys would prevent the formation of that compound.

Mr. W. A. Gatward: As to the question of license, I am only a poor humble engineer and not prepared at all to wander into the field of patent litigation. I may say, however, that there is no license on the use of nickel-chromium for mechanical purposes. The license is required only for heating devices.

The use of nickel-chromium for sugar containers has never been investigated but could easily be done by trying out a small

dish. The alloy certainly would not contaminate the sugar as much as iron. Nickel or "Monel metal" would be cheaper.

That, gentlemen, concludes my list of questions and I thank you for your attention and the interest you have shown in my remarks this evening.

Dr. John S. Unger, *Chairman*: We have listened to Mr. Gatward's paper with great interest, at least I have been interested from the beginning. We are living in an age of alloys, many of which have come to stay. They are finding their uses in the arts, and there is a wide field for development and study all along the line of alloys.

STELLITE AND STAINLESS STEEL

By Elwood Haynes*

The three metals, iron, nickel, and cobalt, are termed by chemists the "metals of the iron group." The reason for classifying them thus is the fact that their respective properties are all quite similar.

1. They are all distinctly malleable.
2. They are all distinctly magnetic.
3. They possess high tensile strength and high modulus of elasticity.
4. When pure, they take a high polish and show a distinct metallic luster.

They also resemble one another in their chemical properties.

1. Each is readily soluble in nitric acid.
2. Each forms a monoxid with oxygen, as FeO, NiO, and CoO. Each also forms a sesquioxid, Fe_2O_3, Ni_2O_3, and Co_2O_3.
3. Aqueous solutions of their chlorids, when evaporated to dryness, are transformed into oxids.
4. Their oxids are all readily reduced by either carbon monoxid or hydrogen.
5. Their melting points coincide quite closely.
6. Their atomic weights are quite close together, that of iron being 56, and those of cobalt and nickel approximating 59.

When solutions of cobalt and nickel are mixed, it is difficult to separate the metals one from the other, owing to the fact that their behavior under most precipitants is practically the same.

In 1899, the writer produced an alloy consisting of practically pure nickel and pure chromium by heating their mixed oxids with

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aluminum. This alloy, when polished, retained its luster, even in the atmosphere of a chemical laboratory, and proved to be practically insoluble in nitric acid, even when boiling. It is also malleable when cold, and under proper annealing can be worked into sheets and wire.

Shortly afterward, an alloy of cobalt and chromium was produced, which not only showed the same untarnishable properties as the nickel-chrome alloy, but possessed much greater hardness. The alloy could not be worked to any extent cold, but was found to be malleable at a bright orange heat.

It was not until 1906 that the alloy was produced in sufficient quantity to determine its properties fully.

In 1909, a cutting blade was made of the alloy, which took an edge comparable to that of tempered steel.

Later, tungsten or molybdenum was added, and the alloy thus produced was sufficiently hard to turn iron and steel on the lathe. Later experiments demonstrated that such alloys when properly formed, would scratch any steel, and would stand up under much higher speeds on the lathe than the best high-speed steel tools. This fact gave the cobalt-chromium-tungsten alloy termed stellite (from the Latin word, *stella*—a star) a field of its own, and placed it in a class by itself as a material for high-speed tools.

Generally speaking, the cobalt-chromium alloys possess three distinctive properties; namely:

1. They are untarnishable under all atmospheric conditions, and immune to nearly all chemical reagents.
2. They possess great hardness.
3. They retain their hardness up to visible redness.

Some of the stellite articles for ordinary use are formed from alloys of cobalt and chromium only. This alloy answers well for table knives, spoons, etc. The harder edge tools, such as pocket-knives, surgical instruments, etc., contain in addition to cobalt and chromium a certain amount of tungsten to give them greater hardness, while in other instances a certain amount of iron is introduced into the alloy to soften it so that it may be

more readily worked. Such articles include table-knife blades, pocket-knife handles, certain dental instruments, etc. When iron is added to the alloy, the resulting mixture is termed "Festel metal," being made up from the chemical symbol for iron (Fe) and the first syllable of stellite.

This beautiful and easily workable alloy is well adapted to the manufacture of fine door latches, door-knobs, and high class sanitary fittings for bath-rooms, lavatories, etc. It is not malleable except at a bright red heat, but when a certain portion of nickel is added it may be worked cold on the lathe or under the file. By suitable means, it can be given a beautiful stippled surface resembling that of frosted silver, and it is needless to add that under all conditions it retains its luster in the most satisfactory manner.

Some of the later stellite alloys have shown most remarkable resistance to chemical reagents. One of these, possessing quite high chromium, takes a magnificent polish, resembling that of burnished silver. This alloy retains its luster perfectly in boiling *aqua regia*, and is not affected in the slightest degree after immersion in that liquid for a period of 14 days. It is slowly attacked by cold hydrochloric acid, but is practically immune to cold, strong sulphuric acid, and nearly immune to the same acid in the diluted form. It is of course strictly immune to nitric acid of all strengths.

Balance weights made of this material retain their luster under the most trying conditions. They are immune not only to the ordinary fumes of the atmosphere, such as hydrochloric acid, ammonium chlorid, nitric acid, hydrogen sulphid, etc., but even to moist chlorin gas. They present a beautiful appearance, owing to their superb luster, and are so hard that their loss from ordinary wear will be perhaps unweighable for several years. There seems to be no good reason why they would not answer equally as well as the more expensive platino-iridium alloys for standard weights and measures.

In the year 1911, I made some experiments on alloys of iron and chromium with a view to ascertaining definitely their properties. I quote from my notes as follows:

"*November 15, 1911.* While I have known for some time that chromium when added to iron or steel, influences or modifies their properties in a marked degree, I am now engaged in gaining a definite knowledge of,

a. The effect of chromium on the resistance of steel and iron to chemical and atmospheric influences.
b. The effect of chromium on the hardness of iron and steel.
c. The effect of chromium on the elasticity of iron and steel.
d. The effect of chromium on the cutting qualities of iron and steel.

The preliminary experiments which I have already made along this line indicate that the effect of chromium on iron and steel is much the same as on cobalt and nickel.

I have already prepared the following alloys:

a. Alloy 20-C. 79.4% iron, 20% chromium, 6% carbon.
b. Alloy 15-C. 84.4% iron, 15% chromium, 6% carbon.
e. Alloy 5-C. 95.0% iron, 5% chromium.
f. Alloy 10-C. 90.0% iron, 10% chromium.
g. Alloy 15-C. 85.0% iron, 15% chromium.
h. Alloy 20-C. 80.0% iron, 20% chromium."

A number of additional experiments were made during the following winter, and the following was recorded later:

"*April 2, 1912.* A sample of chrome iron was made by melting granulated iron, 100 grams; chromium, 17 g.; ferro-titanium, 2 g.

The metal fused perfectly and was very fluid. Just before pouring, about 1 g. of manganese was added. The two bars weighed 118 g. The 5/16" square bar was forged into a thin edge, which was quite hard and elastic.

April 3, 1912. Fused 100 g. iron, 17 g. chromium, 2 g. ferro-titanium, 3 g. calcium carbide, in a covered crucible same as above. The bars weighed 118 g. The 5/16" bar was hammered into a cold chisel, which would cut iron and soft steel. It was very difficult to file. It should contain about 1% carbon. It did not seem to differ much in hardness from the sample F-2. The crucible was deeply eroded inside, which was no doubt due to the lime from the calcium carbide.

Experiment H-2. Fused iron, 100 g.; chromium, 17 g.; carbon, 2 g.; ferro-titanium, 2 g.; in a covered 'clay' crucible.

The bars were not weighed, but the metal poured clean. The 5/16" bar was forged into a cold chisel. It seemed somewhat harder than the preceding. It forged well, but showed a very small crack at the chisel end, which was ground out before the forging was completed. The chisel

showed excellent cutting qualities. It would nick ordinary stellite with but little effect on the edge.

The chisel end was heated to about 800° C. and quenched in water. This seemed to harden it to some extent and if pressed hard it would just scratch glass. It takes a fine polish but shows rather dark color. It is not acted upon by cold nitric acid, either strong or dilute, and the acid shows only slight residue when evaporated to dryness on the surface of the metal.

April 4, 1912. 80 g. iron, 15 g. chromium, 4.5 g. molybdenum, 2 g. ferro-titanium were melted in a covered crucible. The 5/16" bar was forged to a cold chisel edge. It would cut nails, etc., very well indeed. It seemed also to harden considerably when heated to an orange color and dipped into water. It was afterwards made into a wood chisel which took a keen edge and showed fine cutting qualities.

April 8, 1912. Two ½" square by 11" bars were cast one from mixture F-2, and one from mixture H-2.

Each bar was manufactured into boring bits by the Rockford Bit Works.

Two bits were obtained from each bar and one from H-2 was broken and one from F-2 was 'lost' in going through.

These bits were ½" in diameter and about 10" long. Just before finishing they were annealed in lead which rendered them sufficiently soft to be filed. They were afterward reheated and allowed to cool in the air, when they became so hard that a file had but little effect upon them. They would bore wood fully as well if not better than an ordinary bit. They hold their luster in the air under all conditions."

In order to make sure that such alloys were unknown at this time, letters were written to practically all the large steel producers of the United States, asking for a non-rusting or non-tarnishing iron or steel alloy, but the replies received were all of a negative character, and showed that no such alloy existed, but suggested the possible use of alloys of nickel and iron, but in no case was chrome-iron or chrome-steel even mentioned.

The experiments recorded above distinctly show that the non-corrosive qualities of chrome-iron and chrome-steel alloys were not only discovered by the writer at the time specified, but that their physical properties were also fully demonstrated.

It is useless, and would be out of place in this connection, to take up the question of patents on these alloys, but, as is usually

the case, as soon as the patents were granted, a number of persons came forth with similar compositions, claiming that they had used them for some little time, or that they were different in composition from those recorded in the patent. It is perhaps proper to state in this connection, however, that the discovery rests not on the possibility of adding to the steel other elements which may render it more or less immune to corrosion, more easily or less easily workable, but upon the fact that immune chrome-steels must contain more than eight per cent. chromium, though for certain purposes they may contain much more than that amount, even up to 60 per cent.; that such steels are distinctly workable and useful, whether subjected to heat treatment or not; furthermore, that the proportion of carbon may be raised as high as two per cent. without materially interfering with the untarnishable qualities of the alloy, though such alloys are, generally speaking, more easily worked if the carbon is below one per cent.

Numerous metals may be added to stainless or rustless steel, and some of these may contribute slight benefit, while others may be slightly detrimental. Among these are nickel, cobalt, vanadium, silicon, boron, tungsten, molybdenum, titanium, and tantalum. It is evident that an indefinite number of alloys could be thus formed, some with and some without the above elements, but none would be stainless unless it contained the proper amount of chromium, which is the essential element to be added to nickel, cobalt, or iron to produce a stainless alloy.

About two or three years after the discoveries recorded above Mr. Harry Brearley, of Sheffield, England, discovered practically the same properties in chrome-steel, and I am practically certain that his discovery was made independently of any discoveries made by me.

Immediately after making the discoveries recorded above, I applied for a patent, but my application was not at first granted, on the ground that chrome-steels were not new. Without going into details, I will say that I later made a second application, and that about fifteen days later, Mr. Brearley filed an application for practically the same thing. The United States Patent Office granted a patent to Mr. Brearley on the ground that his applica-

tion contained a provision that it was necessary to polish and harden the steel in order to render it immune. This, however, was later found not to be correct, and in May of this year practically all of the claims in the application of the writer were granted by the Patent Office.

A personal service corporation was formed in this city, to which both the Haynes and Brearley patents were assigned, and licenses have now been granted to the principal steel makers for the manufacture of stainless steel under these patents. This corporation is the American Stainless Steel Company, with offices at present in the Oliver Building, Pittsburgh.

Stainless or rustless steel consists essentially of an alloy of iron and chromium, containing usually from 0.1 to 1 per cent. of carbon, though the latter element may be present up to nearly 2 per cent. without interfering seriously with the working qualities of the steel.

Owing to the high percentage of chromium and its tendency to oxidize at the melting point, even in the presence of carbon, it has been found advisable to melt the steel either in crucibles or in the electric furnace. After melting, the metal may be poured into ingot molds in the usual manner, and the ingots thus obtained may be forged or rolled into bars or sheets. If the ingots are of comparatively small size, they will be found to be very hard after casting, especially if they have been stripped hot and allowed to cool rather rapidly in the air. Indeed, small bars thus produced are likely to be almost file hard.

If a small piece of the steel thus produced be placed in a beaker with a piece of ordinary steel and covered with nitric acid, the ordinary carbon steel will be dissolved with great violence while the chrome-steel will remain utterly unchanged, thus proving that its immunity is primarily due to its composition. This is true whether the steel contains carbon in large or only minute quantities.

Cold chisels cast in iron or graphite ingot molds are sufficiently hard, without tempering, to cut ordinary iron or steel.

By heating cast bars to a bright orange temperature, they can be forged pretty readily into various forms. After the forging is completed, the metal may be allowed to cool in the air, and

will be found to possess remarkably fine grain and good cutting qualities.

Quenching in water enhances the hardness to a considerable degree, particularly if the steel contains more than 0.4 per cent. carbon. It is best, however, to use oil for quenching, in order to avoid local contraction stress in the finished article, which might cause it to break under slight shock or jar.

Notwithstanding the comparatively high temperature of working this steel, the bars show almost no scale during the forging operation, and when finished are covered with a blue-black "skin" consisting of a thin film of oxid.

Owing to the absence of deep oxidation and resistance to deformation at comparatively high temperatures, the alloy is admirably suited for casting engine valves and distilling apparatus, and for many other purposes of like nature. When ground and polished, the alloy resists tarnish to a remarkable degree. It is superior in this respect to brass, copper, and nickel plate, and far superior to any other steel yet produced. Axes, hatchets, saws, or chisels made from it, not only will not rust in the atmosphere, but are unchanged when exposed to salt water or salt air. It will likewise doubtless find a large use in the manufacture of propeller blades for steamers, since its modulus of elasticity is much higher than that of bronze, and it resists the action of both fresh and salt water perfectly. Its great strength and comparatively high elastic limit are likewise in its favor. It will doubtless also have a large application in the manufacture of pump-rods, cylinder linings, pump valves, etc.

It is slowly attacked by dilute or strong sulphuric acid, and also by hydrochloric acid; but nitric acid has little or no effect upon the polished surface of the metal. When properly made it is impervious to practically all the fruit acids, including strong vinegar.

The alloy will fill a long-felt want among carpenters and others using wood cutting tools, since its freedom from rust, together with its capability of taking a keen cutting edge, renders it admirably suited for wood working tools. As noted above, it has been made into auger bits, and these have remained bright for years under all sorts of atmospheric influences.

DISCUSSION

Dr. John S. Unger, *Chairman*:* About the beginning of this century the world was startled by the investigations that were brought to public attention by two men at that time working for the Bethlehem Steel Company—Messrs. Taylor and White—who had made a number of investigations with tool steels containing from two to four per cent. chromium and four to eight per cent. tungsten. They found that after giving their steels a special heat treatment, the steels possessed the property of retaining their hardness at a dull red heat—or what is known as red hardness. These steels differ from ordinary carbon tool steels, owing to the fact that, on account of their ability to retain their hardness at a dull red heat, they were able to cut at a much higher speed and to do more work in the same time, thereby revolutionizing the machining of steel. We might say that the advent of the high-speed steels is responsible for an increase in the cutting efficiency of tools of approximately four or five times.

One of the investigators entering the field departed radically from the steel alloys used by Taylor and White. He was not satisfied to make a metal largely composed of iron with some chromium, tungsten, or other element in its composition, but he invented an entirely new alloy containing very little iron. Roughly it might be said it was made up of one-half cobalt, one-fourth tungsten and one-fourth chromium.

Mr. Haynes, the speaker of the evening, has made a most careful study of the alloy to which I refer, known as stellite, and also of another steel known to-day as stainless steel, and it has been a great pleasure to have him address the Society.

Mr. W. Tallmadge:† What is the tensile strength?

Mr. Elwood Haynes: Perhaps a maximum of 160 000, with a fair elongation, varying with the treatment, from six to eight per cent.

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†Service Department, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

Mr. D. H. Horne:* What is the reduction in area?

Mr. Elwood Haynes: The reduction in area of a bar of that kind would not be over six to eight per cent. It is not very marked. Sometimes it breaks off without reduction, owing to a strain in tempering, perhaps at the point of rupture. That is a question of heat treatment.

Mr. V. C. Allison:† What is the effect on stellite of chlorin at 400 degrees C.?

Mr. Elwood Haynes: It would probably be attacked at that temperature, as would almost any known metal, especially if it is thin. This high-chrome stellite alloy was exposed to moist chlorin for two or three days at air temperature without any effect.

Mr. V. C. Allison: Have you tried out the stellite and stainless steel for diaphragm work, and what is the elasticity of these alloys?

Mr. Elwood Haynes: Stellite would show an elastic limit under tensile stress of probably 120 000. It would answer very well for diaphragms if the amplitudes are not too great.

Mr. W. J. Merten:‡ In the course of your paper you spoke of a high percentage of chromium in stellite. My understanding was that your practice is to keep the chromium content at 15 per cent. in all stellite used for cutting tools.

Mr. Elwood Haynes: We now run chromium higher than that. We run up to 30 per cent. in stellite.

Mr. W. J. Merten: Do you recommend the presence of iron as one of the components of cutting tools?

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†Chemist, U. S. Bureau of Mines, Pittsburgh.

‡Research Engineer, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

MR. ELWOOD HAYNES: No. We can use it up to six and eight per cent. but we do not advise it. If the tool is well treated we advise no iron whatever. The iron softens it some but seems to increase its edge strength. We can secure the same effect by cutting down the tungsten and chromium and increasing the cobalt.

MR. W. J. MERTEN: My experience with remelting of stellite scrap confirms your statement. As soon as I have any iron present at all, it seems to soften the tool and cause deterioration of the cutting properties.

MR. ELWOOD HAYNES: Yes, but in cutting soft metals it does no harm unless you want to get high speed.

MR. W. TALLMADGE: Can you get good pump-runner castings, as compared with "Monel metal," for application to centrifugal pumps? With "Monel metal" we lose a good many castings through shrinkage causing cracks that cause the parts to leak or to be weak. How can your "Festel metal" compare, and do you have trouble from this?

MR. ELWOOD HAYNES: We can cast from stellite as satisfactorily as from "Monel metal." I have handled both, and for the avoidance of difficulties in casting I prefer stellite.

MR. W. TALLMADGE: Is any one ready to produce castings of this kind?

MR. ELWOOD HAYNES: We now have a department for that work in stellite, and I think we can produce results. We are glad to make any experimental forms that are desired.

MR. PHILO KEMERY:* In how large batches do you make your stellite?

MR. ELWOOD HAYNES: We usually melt between 500 and 1000 pounds in a melt, but we make quite a number of melts in a day. We have a capacity for melting a ton or two tons in a day.

*Superintendent, Open-Hearth and Crucible Furnaces, Crucible Steel Co. of America, Pittsburgh.

Mr. Philo Kemery: In a crucible?

Mr. Elwood Haynes: No, by electricity. We do not place more than 20 pounds in a crucible.

Mr. E. D. Leland:* We have all been exceedingly patriotic in our support of the Government these last few years, and we realize the important part that was played by the artillery during the great war. We will all be much interested, therefore, if Mr. Haynes will kindly tell us of the help afforded by his stellite in enabling this country and our allies to turn out the thousands of projectiles used in overwhelming the enemy in the vast artillery contests that occurred.

Mr. Elwood Haynes: We have no definite record, but our men claim that stellite was used in the rough turning of three-fourths of all the shrapnel made in this country during the late war.

Mr. G. Kronfeld:† Practically every company manufacturing shells in the Pittsburgh district used stellite for the finish turning operations. Only one company could not use it and this was due to the fact that an increase in the speed of the machines could not be attained without excessive expenditure and loss of time.

For rough turning, successful tests had been conducted. Most of the shell manufacturers in the Pittsburgh district had already installed or were installing equipment for rough turning with stellite when the armistice was signed.

Mr. Elwood Haynes: The last year of the war we delivered about three million dollars' worth of stellite, for war purposes principally.

Dr. John S. Unger: What prompted you to replace the nickel by the cobalt alloy in that chrome-nickel alloy?

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MR. ELWOOD HAYNES: I was hunting for an edge tool that would not tarnish: the nickel alloy was not hard enough and it occurred to me to use cobalt instead of nickel, and I thus secured the desired result.

DR. JOHN S. UNGER: Can you give us approximately the tensile properties of stellite?

MR. ELWOOD HAYNES: Perhaps a good representation of malleable stellite would be 80 000 elastic limit, 110 000 tensile strength, and with an elongation of nine per cent.

DR. JOHN S. UNGER: In the story you told about boring the cylinders in which you discovered its wonderful machining properties, were the bits high-speed steel or ordinary steel?

MR. ELWOOD HAYNES: They were high-speed steel—the very best obtainable.

DR. JOHN S. UNGER: We know that when iron is immersed in strong nitric acid it is rendered passive and will not go into solution. In dilute nitric acid it dissolves readily. Is that true of stellite?

MR. ELWOOD HAYNES: No, it is different under all circumstances and apparently does not become passive at all. When you pour cold acid over ordinary iron, it will become passive but if you apply heat and start the water to separating from the acid the metal will be attacked very violently. Iron is immune only if the acid is cold and strong.

DR. JOHN S. UNGER: In ordinary stainless steel, I have found that the carbon ranges between 0.3 and 0.5 per cent., and chromium is approximately 12 to 14 per cent. Do you find that by increasing the carbon to as much as 1 per cent. you have any difficulty in forging? I am asking for this reason: I have some table knives of stainless steel which show a number of fine seams near the cutting edge, which looks as though they may have

given some trouble in forging. Is it necessary to keep the carbon low to get a good forging steel?

MR. ELWOOD HAYNES: I do not think so. It does not weld well. The oxid of chromium would not only prevent the welding but it would fail to flux out when you attempt to make the weld. If you get a bad seam it would not melt together or disappear as it would in ordinary steel.

DR. JOHN S. UNGER: After you had discovered the properties of this chrome-cobalt, why did you add tungsten?

MR. ELWOOD HAYNES: For the hardening effect.

MR. G. KRONFELD: Have you done any experimenting with stellite crucibles to replace platinum?

MR. ELWOOD HAYNES: Stellite will not replace platinum. It makes a good ignition crucible for certain purposes. It oxidizes when heated to a red heat and the surface merely turns a blue color. After that it does not change, at least not materially. I had a wire at a bright red heat for a thousand hours and weighed it in a balance that would detect 0.1 milligram and there was no change whatever. But if any attempt is made to use a stellite crucible for fusing the caustic alkalis or decomposing the silicates, the chromium in the stellite will be attacked; therefore we do not recommend it for that purpose. It is very useful, however, for handling alkaline solutions. It will stand boiling in them; but if it is expected to retain its polish and not be covered with a film of oxid it must not be heated above a red heat.

MR. W. TALLMADGE: Have you made any experiments on erosion from the effects of abrasion, such as the wear from water rapidly passing over the surface of the parts of a pump runner?

MR. ELWOOD HAYNES: It is very satisfactory. In the first place it is harder to grind than any steel, because steels do not resist erosion or abrasion to any remarkable extent. The hard alloys do not show as high scleroscopic or Brinell tests as the high-speed steels, but they work very much better because their abrasive hardness is very great.

These two properties are not always fully understood. Some of us have thought that if we put a bar of steel under the scleroscope and it shows a high test, it is an extremely hard steel which would resist abrasion. A steel of that kind has a high elestic hardness, but not necessarily a high abrasive hardness.

A vanadium steel of moderately high carbon and hardness will throw the hammer very high and the scleroscope test may show a hardness of 90, but at the same time you can take a file and file it with ease.

Stellite alloys are just the reverse. They show a low elastic hardness and a very high abrasive hardness. For example, I once made an experiment with a high-carbon steel bar four inches in diameter and 12 inches long, containing about 1.2 per cent. carbon. The bar was heated to a good cherry red and quenched in oil. Afterwards it was drawn to a blue color, which would give it moderate hardness. It showed a scleroscopic hardness of 72. I put the steel bar in a lathe and tried to turn it with high-speed steel, but found that it was impossible to start a cut with any speed or feed. Then I used a stellite tool on the same steel bar. With the initial contact it snapped a little piece out of the bar and then began to cut, cutting a shaving out of the bar the full length, notwithstanding the fact that the scleroscopic hardness was 72 as against only 62 for the stellite. That is accounted for by the fact that there are crystals in the stellite, held in place by a matrix that is softer. Those crystals are extremely hard. They are probably the carbids or triple carbids of tungsten or chromium and possibly of cobalt, though that is not very hard. Carbid of tungsten is close to the diamond in hardness, while carbid of chromium is possibly a little harder than quartz. In stellite these crystals are held in place by a softer matrix of cobalt and chromium, hence the high abrasive power.

Mr. Paul Demmler:* What is the average carbon content of stellite?

Mr. Elwood Haynes: We like to have it above 1.5 and not over 2 per cent.

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MR. W. J. MERTEN: In the earlier experimental stages of your work on stellite, you had been using molybdenum. Why did you abandon it in favor of tungsten?

MR. ELWOOD HAYNES: For commercial reasons. We could not get molybdenum. It was \$1.80 a pound, then \$2, \$3, and \$6 and then the producers told us they could not furnish it at all.

MR. W. J. MERTEN: Then molybdenum worked as well as tungsten as a hardener?

MR. ELWOOD HAYNES: In some respects. We have since made standard compositions and we do not like to change them.

MR. W. J. MERTEN: Was Marsh's work with "Nichrome" earlier or later, or simultaneous with yours?

MR. ELWOOD HAYNES: I suppose I would be telling secrets out of school if I told that. I discovered the alloy and he discovered the resistance qualities in it. He uses it for resistance wire. We made a gentlemen's agreement that neither would go into the other's field. That is better than to have a law suit.

ELECTRICAL OPERATION OF GATE-VALVES

By Peter P. Dean*

OUTLINE

Introduction
Application to Power Stations
Application to Water-Works
Application to Dry-Docks
Application to Refrigeration
Application to Oil Refineries
Description and Discussion of Valves

INTRODUCTION

Judging from the absence of electrically operated valves in large power and water plants, it seems that their application and use has been somewhat overlooked, but upon further reflection there seems to be a legitimate reason for this.

Valves are a very small part of the power engineer's equipment, and their choice receives no undue consideration from him. If he is sufficiently interested he calls for power operation of valves, but, if not, the valve salesman seldom calls attention to the advantages. Little advertising is done by the valve manufacturers, and nobody seems interested enough to start a campaign of education, which is very necessary in order to promote sales.

Until the last year or so, therefore, use of power operated valves was very meager.

The valve manufacturers are essentially mechanical engineers, always busy with quantity output of iron and steel, and the applications of electricity are quite foreign to the majority of these men. Seldom do they employ electrical men other than factory electricians, and they, therefore, depend upon outside aid and the motor manufacturers for information as to the proper type of motor and control.

On the other hand, motor manufacturers seem to express very little interest in the subject, since the demand is not suffi-

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ciently large to warrant special designs being prepared, and the net result is that the valve man is left entirely to himself to secure the proper control equipment.

The control gear—such as switches, limit mechanism, etc.—is also quite a problem and to be successful the application, as a whole, necessitates careful study by engineers familiar with valve construction and use, and also familiar with the application of electric motor control.

Assuming that the engineers are able to purchase a successful control, a still greater problem arises as to where such valves can be successfully used without going to the extreme. Steam lines and water lines necessitate hundreds of valves—many of equal importance—and, since cost prevents motor operation in every case, careful study must be made of their economical use.

Since the use of power operated valves cannot be discussed generally, and without reference to their importance, size, and location, I shall endeavor to show the advantages of their use in specific locations.

APPLICATION TO POWER STATIONS

The high-pressure steam header probably merits first consideration, especially in view of the extremely high pressures and the high superheat generally used. Valves in these lines are necessarily placed in rather inaccessible locations quite a distance from the boiler-room floor, and I have noticed that platform galleries are very often omitted. Whether operated by power or by hand, it is highly essential that means be provided to reach every valve without ladders or scaffold.

In the modern central station, the most important valve is the one situated in the turbine lead, between the header and the turbine throttle. This valve is usually from 16 to 20 inches in diameter. The throttle is usually of the emergency trip type and, in case of failure or sticking, a quick closing lead valve is a necessary protection to the turbine in case of over-speeding or a line fracture.

Hand operation of such a valve takes two men about five minutes, depending upon its accessibility, whereas electrical operation in 30 seconds from one or more safe points is the surest

means of protection against loss of life, and complete shut-down of the station.

Highly superheated steam of 325 pounds pressure provides its own argument for the maximum protection of the lines, which is, of course, impossible without power operated valves.

Sectionalizing header valves are also of considerable importance, and a well laid out control scheme allows of very flexible handling of the complete system from a thoroughly safe operating point.

Next of importance, in a large power-plant, are the water circulating valves between the pumps and condensers. These usually run from 24 to 54 inches in diameter and convenience alone easily justifies the use of power operation, since it requires from 20 to 40 minutes to close by hand.

APPLICATION TO WATER-WORKS

In water-works installations, and distribution systems, the valves are quite large and take considerable time to operate. Motor operation on the pump discharge valves and on the principal valves around the pumping station would result in the saving of an enormous amount of time and labor. In filter plants, power operated valves have been more frequently used, as these call for frequent operation.

Power operation of large distribution valves for water-works is seldom given any attention, despite the fact that enormous losses are sustained each year, due to breaks in the water-mains with no quick means available for stopping the flow. These valves form a particularly good argument for power control on account of their size and the location, and the physical effort necessary to operate. Distribution mains in large cities usually run through congested districts where a bad break would cause considerable damage and we have an instance before us where the main transportation system of a large city was entirely suspended for nearly a day due to flooding from a fractured main.

It is of interest to note that the city of New York, has in operation nearly three thousand miles of water mains, exclusive of high-pressure fire service, necessitating some 66 350 gate-

valves ranging in size from 4 to 60 inches and including some seven hundred valves of 24-inch diameter, and above.

APPLICATION TO DRY-DOCKS

Power operation of flooding and unwatering valves and sluice-gates used in floating dry-dock operation, is being given considerable attention by dock engineers. A 20 000-ton sectional floating dry-dock contains anywhere from 36 to 72 valves of from 12 to 24 inches diameter, which are submerged, and operated from floor stands on the deck some 40 to 50 feet above. In order to raise and lower a boat, the valves must be operated in numbers, formerly requiring several men to whom instruction had to be given by the dock master in charge of the operation. The modern scheme is to place the control of the complete plant of valves and pumps at one control station, so placed that a good view of the complete dock operation is obtained. This not only saves considerable time, but eliminates the possibility of misinterpreting signals and allows the boat to be raised on an even keel, without danger.

APPLICATION TO REFRIGERATION

Electric control of ammonia valves has been little used, but is of the utmost importance on account of the deadly effect of ammonia gas. In case of a bad leak of ammonia, it is dangerous to remain in the atmosphere even long enough to close the valves and in some cases, to provide for such an emergency, the ammonia pipes are brought to the street and there provided with valves that can be shut off from the outside.

APPLICATION TO OIL REFINERIES

Valve houses in oil refineries, containing some hundreds of oil distributing valves, provide an important application, since the pressure is usually extremely high and such control would provide means for isolation in case of fire.

DESCRIPTION AND DISCUSSION OF VALVES

You are all familiar with most of the standard kinds and makes of valves used to-day so I shall touch only upon those adaptable to power operation, and for that reason will not include

valves of the non-return, globe, throttle, atmospheric release, or check type.

For high-pressure steam lines, use is made almost entirely of cast-steel, outside screw, and yoke gate-valves which are made in three patterns: namely, the solid disk, or taper wedge, the tapered-seat double disk, and the parallel-seat double disk. The Ferranti, or Venturi type is also used to some extent. The body and bonnet are of cast-steel—also the gate—while the seat and seat rings, together with the stem, are of "Monel metal," which is ideal for high temperatures. It is non-corrodible, and has a melting point of 2480 degrees F., besides possessing a tensile strength of 70 000 pounds for cast metal and 105 000 pounds for rolled metal. Such valves are constructed for a working pressure of 350 pounds and a total heat of 800 degrees F.

One cannot always account for the choice between the use of the solid-wedge and the double-disk type of steel valve, and their purchase seems to be governed by the experience of the purchaser. It seems curious to note that while some manufacturers are discontinuing the manufacture of solid-wedge valves, others are producing new patterns and strongly advocating their use.

The solid-wedge valve has the advantage of a small number of parts, but it requires very careful workmanship on the seat and seat rings, in order to be tight. A slight difference of expansion of the "Monel metal" rings is also apt to cause a leaky valve.

Valves of double-disk construction, having pivoted disks, adapt themselves to the seats and with the aid of the pressures usually remain tight, and in my opinion the pressure on the disks does far more toward keeping any gate-valve tight, than any form of wedge or wedging mechanism. Maximum pressure always exists between the disks and forces the farthest one to a tight seat.

During the course of some experiments with this type of valve, I have found it possible to release the wedging mechanism completely by turning the hand-wheel one revolution towards opening, with full pressure on one side of the disk and without the valve showing any sign of a leak—which clearly demonstrates that pressure alone makes it tight. In this case it is noted that

one manufacturer of high-pressure steel valves lists a parallel-seat valve having two loose disks with no means except the pressure to keep them tight against the seat.

Low pressure, cast-iron valves are used entirely for circulating condenser water, and are built to stand about 20 pounds pressure per square inch.

The inside screw and the outside screw and yoke types are used, being of cast-iron with bronze seat and seat rings and manganese-bronze stem. These are usually of the parallel-seat type.

Another similar type of valve used in turbine installations is the atmospheric outlet gate-valve, which is used between the turbine and condenser to serve the purpose of a gate-valve and tee for the free exhaust connection. While this type of valve is not frequently operated, it, nevertheless, lends itself quite freely to the application of electrical operation.

For water-works both standard and extra heavy cast-iron, bronze-mounted valves are used. These are of the inside screw type and usually geared to reduce the turning effort. These usually lie on one side and the gates, which are usually double, operate on rollers and guides.

Of the two remaining types, the single gate-valve is used under light pressure and where the pressure is in one direction—as in sewers, vats, etc.—and the ordinary sluice-gate is used for outdoor operation.

There are three types or kinds of power operating devices for gate-valves; namely, hydraulic, electric, and the water-motor. The piston or hydraulic cylinder valves may be used with steam, air, or water—the latter medium being considered best for general purposes. The cylinders are of cast-iron, and are brass lined, carrying the ordinary hydraulic plunger, and pressure is admitted either above or below the piston by a four-way cock or valve. Remote or distant control of these valves is obtained by using magnetically operated control valves, connected to a source of current such as a power circuit or batteries. In case of the failure of water pressure, provision is sometimes made to attach a stem and yoke so that ordinary hand-wheel operation can be secured.

While this type of valve is extremely simple in construction and operation, it is not suitable for outdoor usage on account of

the possible freezing of the liquid; furthermore, the cylinder cannot be applied to existing hand operated valves, and on account of the size of the cylinder, it takes up considerable room. For filter installations, and where no electric power is available, this type of valve is, of course, ideal.

The water-motor has been used in this country to some extent, but not with any marked degree of success. This type of motor consists of an ordinary Pelton wheel encased in a cast-iron casing and supplied by pressure from the water-main itself. The wheel is of the non-reversing type and in order to operate the valve in both directions an ordinary reverse gear is arranged which must be manually operated.

This valve also freezes, unless it is drained; furthermore, it is very cumbersome on account of its size. It is not applicable to existing valves without considerable alteration and since it has no limit device to disconnect the power when the valve is seated, it frequently jams; furthermore, it cannot be controlled from a distance.

Electrical operation by the aid of a motor geared to the valve-stem and a limit switch for stopping the movement, is by far the most reliable method, but, of course, presents more of a problem.

The principal problem in this, and as a matter of fact in any other system of power operation, is to confine the movements of the valve gate within any precise limits, especially at the closed position. On account of the momentum or overtravel of the motor armature and driving gears, after disconnecting the circuit, it is easily seen that these limits are not easily obtained unless, of course, some quick stopping device such as a solenoid brake is used on the motor shaft. The movement must be accomplished by an electric motor driving the valve-stem through reduction gearing and when the motor has driven the valve gate firmly, but not too tightly, into its seat, it has to be disconnected by some form of limit switch that is also geared to the valve-stem and set to bear a definite relation to the position of the valve gate at all turns. Of course, the armature and gears have considerable momentum and consequently the limit switch has to be set to stop the motor, so that this overtravel will carry the gate tightly into the seat. In other words, energy stored up in the moving parts,

is relied upon to form a tight seat. The momentum of the armature and gears after being disconnected from the circuit depends upon friction between the moving parts and the packing in the stuffing gland; also the pressure on the valve disk—all of which are very uncertain quantities.

If a valve limit is set to close tightly, without pressure on the disk, and with normal or loose stuffing-box, it is easily seen that the limit may have to be changed for actual operating conditions, such as tight stuffing-box and full pressure of the valve disk. In other words, the added friction would be so great as to allow of only a very small overtravel and consequently the valve would not close tightly. If a solid-wedge type of gate-valve is carried too tightly into its seat, it soon upsets the bearing between the gate and the seat ring with the result that the valve cannot be made to close tightly. It is easily seen, then, that the apparatus required to fulfil these conditions must be specially constructed.

The motor is chosen entirely with relation to its starting torque, which must be very high in order to unseat a tight valve gate. It must run at a fairly low speed not exceeding, say, 750 r.p.m., both on account of the gearing to the valve-stem, and because of the armature momentum which must be kept to a minimum, to enable a quick stop and to prevent jarring. The motor must be moisture proof for practically every application, not forgetting the extreme heat to which it will be subjected when operating on high-pressure superheated lines. The temperature in which the motor is expected to operate often reaches 200 degrees F., so that special care must be given to the insulation to withstand this, or deterioration will take place. The machine must be made to work in any position, the bearings being either ball-bearing or of the self-lubricating "Metalline" type. The direct-current winding is usually series or compound, the latter being used so as to prevent an excessive speed of the valve disk after it is unseated. Polyphase alternating current has to be used on account of the poor starting characteristics of the single-phase motor and, for a given size of valve, the alternating-current motor has to be nearly as large as the direct-current machine because the former machine possesses a much weaker starting torque per pound of weight.

The limit switch has to be of the quick-break type capable of being immediately reset after breaking, so as to reverse the valve at any intermittent point. It should be geared directly to the valve-stem, so as not to be upset when the valve is operated by hand.

The controller may be either a plain reverse switch or a panel with indicating lights, to throw the motor across the line without any starting resistance.

These three units, well chosen with regard to their ability to operate together, and applied to a valve, constitute with the reduction gears a most reliable and efficient motor operation and the most nearly perfect that has been developed.

This system has its limitations, however. It cannot be standardized and its use is confined to new installations only, since it cannot be applied to valves already in use without shutting down the line. Direct-current and alternating-current equipments of a given make necessitate different yokes, bonnet castings, and gear ratios to suit the motors; thus, when a different make or speed of motor is used, the castings and patterns have to be altered.

The motors have to be bolted directly to the yoke which on superheated lines is usually extremely hot, and such heat is transmitted through the field frame to the windings with damaging effect.

Different makes of limit switches and panels are used for short and long distance operation as well as for direct and alternating current, so that it is apparent that no standard can be adopted, especially as engineers frequently specify different makes of motors and controllers.

Some three years ago the writer began a careful study of the situation, confining himself entirely to valves and their operation, with the object of designing and building a valve operating device to fulfill every condition of operation.

The Dean system of valve control, which is the outcome of these observations, is built on somewhat radical lines incorporating four special features:

1. It can be attached to existing valves with a medium of effort and without shutting down the line.

2. It is positive in operation and does not depend upon momentum or drift of moving parts to seat.
3. It has ample unseating and seating torque.
4. The whole unit is enclosed and waterproof.

The system consists of a single unit in which are incorporated the driving motor, reduction gear, and limit trip mechanism. The feet of the unit are provided with four holding-down bolt holes of standard dimensions for a given range of valves. Four standard units cover the complete lines of valve sizes in use.

The motor is totally enclosed and waterproof and possesses an extremely high torque. It is connected to a system of combination worm and planetary gearing, for the necessary reduction in speed. The motor speed is normally 1600 r.p.m. and that of the low-speed shaft 40 r.p.m., the gear reduction being 40 to 1. With different gear ratio incorporated in the same casing a reduction of 120 to 1, or 14 r.p.m. on the low-speed shaft is available.

The motor shaft is coupled to the worm shaft, both running in ball-bearings, and the worm-wheel is keyed on to a sleeve forming the sun pinion of a planetary gear. The planet pinions revolve on large studs forced into a flange on the low-speed driving-shaft and these pinions mesh into the internal gear forming the outer member of the planetary. The outer planetary member is provided with two external grooves extending clearly around the surface, each one being provided with a stop. The external member fits into a bearing surface in the casing and is locked in place and prevented from turning by two movable driving plugs extending through the casing and into the grooves.

The valve gate is made to seat tightly, under power, and to a predetermined point, drift and overtravel being entirely disregarded, as a means of seating the gate.

The gearing for speed reduction is encased in a cast-iron housing partially filled with oil so that the gears are always well lubricated.

The limit mechanism is contained in a separate part of the housing and provided with removable cover. A noteworthy feature is the total absence of exposed cables and wires, these being encased in conduit and the joints made waterproof.

For changing a hand operated valve to power operation, the unit is ideal, on account of its compactness. The outside screw yoke valve necessitates only two pads, welded onto the yoke to suit the feet of the unit, and drilled; while the hand-wheel is replaced by a cut gear which is keyed onto the same bearing. A shaft extension is provided for the hand-wheel when necessary.

Valves of the inside screw type do not afford much facility for change—especially those with only one bearing, since this bearing is usually too small to withstand the thrust of a power driven gear.

Control of the valves is by means of one standard control station for one or more points. Stations are fitted with indicating lights and provision is made for locking the operating handle to prevent unauthorized operation. For multiple point control, use is made of a totally enclosed relay panel, which is necessary in order to prevent a short-circuit, should two or more stations be operated at one time.

DISCUSSION

Mr. M. W. Link:* This is the first time I have heard Mr. Dean talk and I fear that most of the members present may feel that the "other fellow" did not do very much work on motor valves. I would like to say that the Crane Company has been fussing with motor valves for about fifteen years. I would like to give just a few of our experiences.

The first motor valve I can remember was designed for a man who had his own ideas. It was a 36-inch gate-valve in a basement, controlling a water line under about a 50-foot head. He wanted a pair of beveled gears coupled to clutches, and a knife switch for the motor. The valve is still in operation. When it was to be opened or closed, the operator would give the wheel a turn with his hand to start the motor. The valve has an indicator.

After that, we were asked to design valves in which the operator could throw a switch and walk away. On the first attempt we had special motors made with a sensitive circuit-breaker. When the valve jammed, the excess current would throw out the circuit-breaker. That was pretty hard on valves and motors. Later we fussed with limit switches. About that time, an engineer in Chicago obtained a patent on a limit switch for motor operated valves, which was nothing but a dial switch like a direct-current motor starter. It worked when it was new, but this type of limit switch, due to the slowness of the break, was such that the contacts burned and stuck. We required a very quick break. We started experimenting with push switches but we could not buy any which would stand temperature, pressure, moisture, and all the conditions of power-house use.

About that time, a concern making control apparatus came to us with what was said to be a real control for valves. It was pretty good, but like all of them it was a "wished on" proposition. It never worked out successfully. Later on, we started fussing with the larger concerns like the General Electric Company and

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the Westinghouse Electric & Manufacturing Company. The General Electric Company sent its engineers to Chicago to co-operate with us, and the construction of a large steel gate-valve was the result of their labors. It was a two-unit proposition. One side was the drum controller and the other side was the motor. We depended on the drift of the motor to close the valve as the rotating drum was not fast enough to stop at the proper time. We have used that control successfully for the last six years. It is expensive and well made.

We made other controls. I remember one job where the electrical engineer had his own ideas and we made a limit switch which was a long stem running in synchronism with the valve-stem, with a switch on each end of it. It worked out pretty well but one day they dropped something on the indicating stem and the entire mechanism was gone.

What I have told you in two minutes represents an experience of fifteen years. We have what Mr. Dean said he could not get; that is, we know what power it takes to open and close a valve—anything from 72 inches down. We did not get together with Dean, because the General Electric Company spent a lot of money with the Crane Company in the development of the control and both wanted to get something out of it; but recently Mr. Dean convinced us that we were foolish to fuss with the two-unit control.

There are several questions which I can answer but I will ask Mr. Dean to start the discussion. I am interested in getting the other fellow's viewpoint. Mr. Dean stated that his control could be used five miles away. In such an installation how many wires are there between the control station and the valve, and are they power wires or control wires?

Mr. Peter P. Dean: Mechanically strong control wires—five between the valve and the control station.

Mr. M. W. Link: Another thing which was not brought out, but which is very important, is pressure control. There are many cases where a pressure-gage, equipped with electric contacts, should be used to open and close valves. We had a case

to-day where a man had a pump in an automatic pump house, and, if there is a fire anywhere, he wishes to press a button, start the pump, prime the pump, and at a certain point cut off the priming by-pass and have the pressure go into his fire line. That is a pretty nice problem because the by-pass around the suction line must open at the right time, the connection to a tank must close at the right time, and the main valve to the fire line must open correctly. We recommended the use of a pressure-gage, as it would do the work and not depend on any man to operate the control. I wonder if Mr. Dean has done anything along that line.

Mr. Peter P. Dean: We have had cases with smaller valves with thermostats.

Mr. M. W. Link: Thermostats and pressure-gages are the same, as far as this is concerned.

Mr. Peter P. Dean: We have a device on a number of steam lines where as the pressure drops very low the electric indicator closes automatically.

Mr. M. W. Link: Another point. In your control, you have a worm-gear which must have lubrication to make it run anywhere near frictionless. Do you have difficulty due to this lubricant becoming solid in an exposed valve?

Mr. Peter P. Dean: In street valves we use exceedingly light oil both in winter and summer and that is confined in a case and the power of the unit is such that it makes very little difference.

Mr. M. W. Link: When you are closing a fairly large gate in a water line, where the water travels from 10 to 14 feet a second, the last few turns require power. I wonder whether in your power curves you have had a chance to determine this power at any time.

Mr. Peter P. Dean: You will find it an exceedingly hard matter to make any such test as that. There is only one plant in the country where you can do it under exceedingly low pressure

and that is at Holyoke, Mass. The question is always brought up in steam line practice as to whether the valve will close in a fractured line with the high velocity steam from the boilers blowing into the atmosphere. We have never been able to make such a test. We believe we can do it if the conditions are provided, but this is almost impossible. We are very much like the little fellow who wanted a job. "What can you do?" he was asked. "I can do most anything." "Can you file smoke?" "Yes, if you will hold it in a vise for me."

Mr. W. C. Hawley:* There are two points regarding which I would like some information. In an ordinary gate-valve in a water line, especially in a water-works distribution system, more or less sediment, sand, gravel, etc., is bound to collect in the bottom of the seat. When this condition exists, the gate or gates cannot be forced into the seat. What happens then, when the effort is made to close a valve by the mechanism which has been described? Is there any provision which prevents the bending or breaking of the stem?

Mr. Peter P. Dean: When a man spends a thousand dollars putting in an electric motor device on his valve we insist that he frequently open and close his valve to keep it in operating condition. If it has not been closed for two years or so, we insist that he overhaul it. You may get gravel under there but it will close just as far as it can. We do not know except from the actual number of turns whether there is any foreign matter there. If there is, the motor will stall and a fuse will blow to protect the motor. That is the only protection we can make.

Mr. W. C. Hawley: Then there is no damage done to the stem; the operation is not continued to the point where the stem would bend or break?

Mr. Peter P. Dean: The unit is not of sufficient capacity to twist off the stem.

*Chief Engineer and General Superintendent, Pennsylvania Water Co., Wilkinsburg, Pa.

Mr. W. C. Hawley: The valve-stem is generally the weak part of a gate-valve—the part that breaks first. In operating a water valve by hand, the operator would close the gates down as far as possible and would be guided by the "feel" and the sound of water cutting through in forming his judgment as to whether or not the valve was closed. If not closed, by raising and lowering the gates a few times, the foreign matter collected in the bottom of the seat is blown out. This would probably be a difficult condition to overcome with a mechanically operated valve and the valve would not be closed tightly enough to permit repairs to be made even though the gates were forced against the foreign matter in the seat until the stem were bent or broken. Besides, if the stem had to be replaced, it would mean the closing of other valves in order to make the repairs, and the loss of much valuable time, to say nothing of the expense.

The other point which I had in mind is the question of water-hammer and the resulting damage on account of the quick closing of valves. In operating a valve by hand, under pressures of from one to two hundred pounds which are common in this district, it is necessary to close very slowly. The men give the wrench a few turns and stop, and then a few turns more. They do not continue turning steadily even at the slow rate at which it is done by hand.

Mr. Peter P. Dean: We have a speed closing ratio for different valves. We can make the valve close in an hour if you wish, or we can make it close in three minutes. Hydraulic engineers usually specify a speed of about eight inches a minute, considering that a safe rate. If the line breaks you simply jam it down.

Mr. W. C. Hawley: Those speeds are all unsafe for valves in water-works distribution systems or supply mains.

Mr. Peter P. Dean: We have had experience with 24-inch valves, and upwards, with a pressure of 100 to 250 pounds, and a speed of about eight inches a minute seems to be satisfactory.

Mr. W. C. Hawley: That is all right for the first two-thirds of the closing but when we get to the last third, and begin to throttle the flow of the water, serious water-hammer will be caused as sure as fate. Instead of jamming the valve down in a case of that kind, it is the universal water-works practice to close slowly so as to avoid water-hammer and the additional breaks and damage which water-hammer is very likely to cause.

Mr. Peter P. Dean: That is a point well taken. The Dean control has a series-wound motor and it automatically adjusts the speed to the load that is put upon it. When you get down to the throttling point it hardly moves, due to the excessive power requirement of the valve. That is taken into consideration in the winding of the motor. We never attempt to use a constant speed, constant torque motor for any such equipment as that.

We have not had any experience with 12- and 14-inch valves under streets but we have a unit small enough and slow enough to give you any speed of opening and closing you want. The ideas of engineers vary considerably on that point. In Scranton, Pa., we have 36-inch valves at 100 pounds pressure that close in 10 minutes, and we have a case of a 36-inch valve that closes in half an hour.

Mr. W. B. Spellmire:* I notice the hand-wheel is generally left on the valve. How do you avoid the possibility of racing that at a high speed?

Mr. Peter P. Dean: It is rather interesting to know that the hand-wheel does not run at excessive speed. A hand-wheel running not to exceed 50 revolutions a minute has so little momentum that the jamming effect is almost negligible. In most large valves we recommend that the hand-wheel be left off and laid by the side.

Mr. George J. Stuart:† I would also like to make a defense of the valve manufacturers and say that they have done their full share in the development of motor-operated gate valves.

*General Manager, General Electric Co., Pittsburgh.

†Chief Engineer, Pittsburgh Valve Foundry & Construction Co., Pittsburgh.

Our experience has been very similar to that outlined by Mr. Link of the Crane Company. About fifteen years ago the motor-operated gate-valve business started and it has been growing very rapidly since that time.

The first machines gotten out were very crude. The current to the motor was controlled only by means of an overload circuit-breaker, and this method of control was found to be thoroughly unsatisfactory. The next general design put on the market consisted of a limit switch working in conjunction with a shunt trip circuit-breaker and a reversing switch. This method of control gave fair satisfaction. It has two weak points, however—one, that it is not fool-proof, and the other, that if some dirt accumulates on the contacts of the limit switch the entire control is inoperative.

One absolute essential of a motor-operated gate-valve is that it must be fool-proof. In my experience in a plant equipped with motor-operated gate-valves of the type last described, an operator ruined six valves in about five minutes. He threw the switch the wrong way—that is, he wanted to open the valve when it was already open—and of course the circuit-breaker opened. He did it again with like results and then concluded there was something wrong with the circuit-breaker and held it in. This is an extreme case but it shows what may happen. This experience led us to the conclusion that the machine must be so constructed that it is impossible for an operator to break anything, even though he should operate the switches improperly. An equipment of this kind has been on the market for about five years with excellent results and is comprised essentially of a mechanically operated circuit-breaker and a double-throw knife-switch.

Mr. Peter P. Dean: Will you say a few words about the large hydraulically-operated, quick-closing valve for which you were responsible—a 60-inch valve that closes in six seconds?

Mr. George J. Stuart: Between Mr. Young, then of the Westinghouse Machine Company, and myself, we managed to get this valve in operation at the plant of the Duquesne Light Company. The valve is a 66-inch exhaust-steam valve and is oper-

ated by means of a hydraulic cylinder. It was designed to close in six seconds; the exceedingly short time allowed for this operation being on account of safety. They wanted to shut the steam off the low-pressure unit as quickly as possible should anything happen. There is very little of note to this design except the bronze-lined cylinder, having large inlet and outlet ports, which, I believe, were four inches in diameter. The cylinder is operated by what is known to us as a four-way Aiken valve. It has a special feature at the point of closing to guard against shock. This feature consists simply of a choker to choke off the water as it leaves the cylinder. There is also a special device in the pipe which allows the valve to operate quickly in one direction and slowly in the other. The valve has been in successful operation for about three years.

MR. PETER P. DEAN: The discussion to-night touched on the type of quick-closing valve used between the header and the turbine throttle. In most of the plants use is made of an electrically operated valve requiring 40 to 50 seconds to close an 18-inch valve. Some engineers say that it is no good if it takes that long to close, and they mention the type of valve used on turbines where they press a button and the complete flow is shut off in a fraction of a second. They say that is the type of valve they want in the lead line. I have not been able to locate a single plant that had any quick-closing valve of that description in the line. Engineers claim they are entirely too delicate and with an excessively heavy overload the shock will almost close them. Furthermore, a globe-valve is used and you will not find globe-valves in a large high-pressure steam lead. Has anybody had any experience in that line?

MR. GEORGE J. STUART: In the various plants with which we have had to do and in the many inquiries that come to our attention I do not recall any plants so piped. I should think the quicker you can close the valve the better, but in the design of valves for this service one should stay away from anything that is delicate. If it has trigger latches that are mere hairs and

things that the least trifle of dust would disarrange I would not trust them.

Mr. B. M. Herr:* I have heard of an automatic engine stop being used for that kind of service. I believe the American Sheet & Tin Plate Company in its lines to engines, uses this type of valve for a quick closing valve should something happen to the engine.

Mr. Peter P. Dean: That valve is an engine-driven device from the fly-wheel, driving a governor. When the engine overspeeds, the spreading of the governor makes a contact, operating a solenoid that shuts down the valve.

Here is another point that is hard to explain. An engineer will specify a solid-disk, wedge-type, gate-valve on steam lines. The next one will specify a double-disk-type, taper seat. A third will use what is know as a Venturi-type valve, where there are two disks just allowed to fall into the space between the seat rings and if there is no pressure in the valve this seat will wiggle around. The first takes a solid wedge that requires considerable machining, and uses extreme power to jam it tight, while the last-mentioned valve just drops into the seat and the steam pressure will keep it tight. All those valves are in use in various high-class plants in this country.

Mr. B. M. Herr: There is a good reason for the parallel-seat type of valve as compared with the wedge type. As the author stated in his paper, engineers have not paid sufficient attention to the design of valves and we believe this is especially true in regard to the distortion of metals under strain and changing temperature. Good valve designers construct the various parts of their valves so that they will resist distortion as much as possible, or in such a way that the distortion will not affect the parts of the valve that must not become warped. The parallel-seat gate-valve illustrates this principle of design very exactly, and the Venturi type to a more extreme degree, since the disks are of smaller diameter than the pipe. The ground joints of the

*District Sales Manager, Edward Valve & Mfg. Co., Pittsburgh.

holding faces are backed up by cylinders which we realize can easily be distorted out of round, but we can hardly imagine a cylinder becoming distorted longitudinally. Therefore, the ground joints are held in a perfect plane and continue to seat properly when the valve is closed, if the seats are clean. From what we have learned from Mr. Dean's remarks, it would appear that this type of valve would also be a more satisfactory valve for the Dean control to handle. Do you find this to be the case; and, if so, why?

Mr. Peter P. Dean: There is just one thing that keeps the valve tight, and that is pressure on the seat. Why wedge it in when the pressure on the seat will keep it tight?

Mr. George J. Stuart: That is true in a valve that is well ground. The pressure is the thing that keeps it tight, but after the valve gets into service and the merest flake of foreign matter gets on the seat it is well to have some wedging device so that you can jam the seats home by hand. I have seen loose valves made tight by working them up and down with the hand-wheel. Of course, the steam pressure multiplied by the area of the disk represents a great deal more pressure than can be exerted by the hand-wheel; but, nevertheless, it has been found that the wedging of the valve is a necessity.

Mr. Peter P. Dean: Isn't this true, that when you pull a solid-disk valve up, the disk does not slide against the seat and so cut the seat; whereas, a loose parallel disk, as you draw it up, will slide over the seat and so cut it?

Mr. George J. Stuart: That might hold true for a good part of the stroke but for the first inch of travel, which is about enough to unseat the valve, there is play enough in the guides to allow the disk to move over and rub against the seat.

Mr. M. W. Link: You have the same problem in the Hopkinson valve. The Hopkinson valve is the finest piece of valve machine work made, and its success is due to this machine work.

I do not know whether people in the United States would pay for that kind of work on an ordinary valve. The parallel-seat valve of the Hopkinson type is a beauty, if properly installed.

I will say, for your information, that engineers to-day are working on 600 pounds steam pressure. I doubt whether there is a gate-valve, Hopkinson included, which will give satisfactory service on 600 pounds, particularly at the velocity which will be used. Steam velocities in this country at 600 pounds pressure should give 20 000 feet per minute. When you try to put a gate-valve or a quick-acting valve in such a line, something is going to happen. The United States Navy is using up to 18 000 feet velocity in its most modern ships.

Mr. Peter P. Dean: Others have attempted it. They had the Buffalo General Electric station laid out for 1000 pounds, but could not get anybody to build the apparatus.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, January 7, 1919, at 4:15 P. M., President W. E. Snyder presiding, Messrs. Hoerr, Neilson, James, Danforth, Mott, Crabtree, Pittman, Kingsbury, Hawley, Duff and the Secretary being present.

The minutes of the last regular meeting held December 3, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Carlson, Justus Ewald Nathanael
Jackson, William
Scott, Guy F.

JUNIORS

Lambie, Aaron Louis
Tyler, Lewis Percy

The following applications for membership were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Kelley, Henry D.
Stephany, Erwin John
Offutt, John William
Anderson, Robert
Elder, David

ASSOCIATE MEMBER

Kronfeld, Gus L. S. (Mem. A. S. M. E.)

JUNIOR

Abramovitz, Hymen Louis

The Secretary announced that Mr. Carroll Miller, who joined October, 1908, and resigned December 1, 1914, desired to be reinstated, whereupon the Secretary was authorized to replace his name on the Society Rolls.

The Secretary presented letters of resignation from the following gentlemen, which after discussion were accepted:

M. D. Cooper	J. B. Luttrell,
E. E. Eby	W. J. Pertz
W. B. Hartman	P. M. Snoeberger
O. P. Hood	A. E. Sortore

E. Stutz

The Secretary read a letter of resignation from Mr. Frederic Ottesen Mr. Snyder agreed to see Mr. Ottesen in an effort to have him withdraw his resignation.

The Secretary reported the death of the following members:

Mr. A. E. Escoreal..Joined Oct., 1913
Mr. J. W. Henderson............Joined Sept., 1915; July, 1912
Mr. Hermann Laub..Joined May, 1902

Mr. Danforth agreed to secure a memoir of Mr. Laub and the Secretary was requested to write Mr. Henry Gulick, business partner of Mr. Henderson, asking him to prepare a memoir of Mr. Henderson.

The report of the Secretary showing the financial condition of the Society November 31, 1918, having been previously audited by the Finance Committee, was approved.

The Secretary read a letter from Mr. F. C. Schatz thanking the Society for the courtesy shown the members of the Truck Owners' Conference at the time of their Convention in Pittsburgh.

Mr. Neilson suggested to the Board that an invitation be extended to Brig. Gen. Edgar Jadwin, to be the guest of the Society upon his return to this country on any date he may designate. After discussion it was moved and carried that the Secretary be requested to write a letter to Brig. Gen. Jadwin on behalf of the Board of Direction.

Dean Mott brought up the question of the demobilization of the 15th U. S. Engineers, suggesting that Board of Direction write the Secretary of War asking that the 15th Engineers be sent to Pittsburgh to be mustered out of Service. It was also suggested that the Engineers' Society might arrange some sort of a program in connection with the demobilization. After discussion it was moved and carried that the Secretary be requested to write this letter and report at the next meeting of the Board.

The matter of finances was brought up and discussed and the Secretary was requested to get up a list of those members in arrears for the next meeting of the Board for their action.

The meeting adjourned at 5:40 P. M.

K. F. TRESCHOW, *Secretary.*

CIVIL SECTION

Annual Meeting

The Annual Meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, January 7 at 8:13 P. M., Chairman George H. Danforth presiding, 41 members and visitors being present.

The Minutes of the last Annual Meeting were read and approved.

Mr. John A. Ferguson on behalf of the Nominating Committee, reported the nominations of the following officers for the ensuing year:

J. H. Minton	Chairman
L. F. W. Hildner	Vice Chairman
C. W. Bretland, L. P. Blum, Paul S. Whitman	Directors

No further nominations being made, the Secretary was instructed to cast a unanimous ballot for the members named, who were thereupon declared elected.

There being no further business, the meeting adjourned at 8:55 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION

Bi-Monthly Meeting

The Regular Bi-monthly Meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday evening, January 7, 1919, at 9:00 P. M. Chairman J. H. Minton presiding, 41 members and visitors being present.

The Minutes of the last meeting held November 12, 1918, were read and approved.

No further business coming before the Section, the paper of the evening on "The Development of Cast Steel Anchor Chain" was presented by Mr. A. E. Crockett, Forging Engineer, Jones & Laughlin Steel Co., Pittsburgh.

Ensuing discussion was participated in by: Mr. E. J. Mason, Asst. Engr., Heyl & Paterson, Inc.; Mr. F. L. Egan, Carnegie Steel Co.; Mr. J. F. Craven, Craven Research Laboratories; Mr. George H. Danforth, Jones & Laughlin Steel Co.; Mr. J. H. Minton, Asst. Engr., Pennsylvania Lines, and the author.

On motion the meeting adjourned at 9:46 P. M.

K. F. Treschow, *Secretary.*

ANNUAL MEETING

The Thirty-ninth Annual Meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Pittsburgh, Tuesday, January 21, 1919, at 8:15 P. M., Past President A. L. Hoerr presiding in the absence of President Snyder, 120 members and visitors being present.

The Minutes of the last Annual Meeting held January 15, 1918, were read and approved.

The annual report of the Board of Direction, which included the reports of the Standing and Special Committees, the Sections and the Treasurer, was read as follows:

Report of Board of Direction

The Board of Direction of the Society held ten regular monthly and four special meetings during the past year, at which routine business of the Society was transacted.

During the year there were eight regular monthly meetings and three special meetings and the annual meeting of the Society. Total attendance was 709, the average being 65. The maximum attendance was 104 at the December meeting and the minimum 28 at the June meeting. The average number participating in the discussion of papers was five.

At the close of the year, the membership of the Society was as follows:

Honorary members	2
Members	991
Associate members	52
Associates	35
Juniors	102
Student Juniors	23
Total	1205
Dropped	28
Resignations	50
Removed by death	13
Total	91
Accessions	89

Respectfully submitted,

K. F. Treschow, *Secretary.*

Report of House Committee

To the Board of Direction
Engineers' Society of Western Pennsylvania.

Dear Sirs:

During the year 1918, the House Committee has not attempted to more than continue past standards in the conduct and equipment of the Society Rooms.

With the exception of undesirable enemy issues, some foreign magazines of most irregular habits and a few minor ones dropped from the exchanges, the familiar publications have been found on the reading tables, though not always with their former punctuality; the Society name has been lettered proudly on two of the most prominent windows; the chess club, more or less half-heartedly, has striven to maintain its mid-day meetings; and the rooms have been kept open evenings as usual, in charge of a competent attendant, with a monthly attendance averaging 55, descending from peaks of 81 and 76 in February and December respectively, to 14 in the dog-days.

Owing to the demands for war activities space in this and contiguous buildings, there have not always been fitting quarters provided for our stated meetings; though such inconveniences seem but trifles to the mother Society when her branch abroad in the ranks of the 15th Engineers, was holding its historic discussions all the way from the English Channel to the Meuse with no roof but the bombarding skies and no walls but the blasting barrage.

Respectfully submitted,

George H. Barbour,
Chairman, House Committee

Report of Publication Committee

President, Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

The Publication Committee would make as its final report for the year 1918, the statement that it has been able, with the aid of the officers of the various sections, to fill all meetings of the year with what we believe have been papers that were unusually acceptable to the Society membership although the times and conditions have not been propitious, and in addition, have been able to leave a well filled schedule for the Committee that will be taking charge of this work in the year 1919.

This work has, at times been very difficult to accomplish in the manner that was considered acceptable, and the Committee wishes to express its thanks and appreciation for all who have so kindly aided them in their work.

Yours very truly,

GEORGE H. DANFORTH,
Chairman, Publication Committee.

Report of Entertainment Committee

Bord of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

During the past year the work of your Entertainment Committee was much restricted on account of war conditions. It was impossible to arrange attractive inspection trips owing to Government restrictions covering the admittance of visitors to plants engaged in Government work. As practically all manufacturing plants in the Pittsburgh District came under the Government ruling, our hands were tied. We did arrange for two trips, but before we had our plans completed, we were asked to postpone our visit indefinitely. This restriction also covered coal mines, so you can readily see why our activities in the line of inspection trips were badly curtailed. This was most unfortunate, as we believe that inspection trips not only result in acquiring valuable information, but also serve in bringing members close together.

The following entertainments were held:

April 13th—Dinner and Smoker at the Fort Pitt Hotel. Attendance 135.
June 22nd—River Excursion. Attendance 98.
November 22nd—Victory Smoker, Fort Pitt Hotel. Attendance 120.

Respectfully submitted,

GEORGE H. NEILSON,
Chairman Entertainment Committee.

Report of Membership Committee

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

During the past two years war work has so engrossed the attention of engineers throughout the country that it has left them little time for engineering society activities, except where such activities were directly

concerned with war work. It has, therefore, been very difficult for any technical society to build up its membership. In addition to this, the increasing cost of living has made the financing of membership expenses a real factor for the younger engineers. With a view to relieving this latter condition, your Society agreed to accept members of the five National societies as members of the Engineers' Society of Western Pennsylvania without payment of the usual initiation fee. Invitations were sent to the local members of these National societies and a number of them availed themselves of this opportunity.

It is our hope that during the coming year the local engineers will have more opportunity for self-improvement and will avail themselves of the opportunities presented by membership in the Engineers' Society of Western Pennsylvania. In 1916, our membership was 1126. This was increased to 1187 in 1917 and to 1198 in 1918. This is a net increase of 72 members over our 1916 total. During 1916, we admitted 99 new members; in 1917, 94 new members; and in 1918, 89 new members. Of these latter, about half were admitted from the National Societies under the special privilege which allowed them to enter without payment of an initiation fee. During 1916, resignations, deaths and other causes removed 102 members from our roll; during 1917, we lost 41 members, and during 1918, 91 members. The Society followed the custom established by other technical societies, of remitting the dues of all members who joined the military organization. With this exception, our membership represents fully paid up members. Delinquents have been dropped from the roll so that the membership to-day is in a stronger and healthier condition than ever before. While the number of men in military service is large for our Society, it does not represent a very large percentage of our total membership, and, therefore, the probable loss in members, due to resignations from this source, is comparatively small. Most of the men who have joined the military organization were men who were active in the society work and who, no doubt, will resume their former activities as soon as they are released from the military organization. A few of these men may remain in the service, and for this reason, may sever their connection with the Society. We do not expect resignations from this group for any other cause.

We are beginning the year 1919 with just two members less than 1200 We have held our organization intact and materially increased its efficiency, as will be indicated by the reports of other activities. We expect an increasing interest in the society work, which should be shown by a large attendance at our meetings and greater interest in the presentation of papers. This trying period, through which we have all passed, has elim-

inated most of our dead wood, so that the future of our Society looks very bright and we believe that we should have a substantial increase in membership during the coming year.

Yours very truly,

H. D. James,
Chairman, Membership Committee.

Report of Civic Affairs Committee

To the Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

The amendments to the By Laws of the Society made during 1917 provided for a Standing Committee on Civic Affairs reporting to the Board of Direction, Section 10 of Article 6 reads as follows:

"The Civic Affairs Committee shall be charged with the duty of investigating and reporting upon the relationship of the Engineers' Society to matters of public interest, and shall take up special subjects assigned to it by the Board of Direction."

On February 20, 1918, Pres. Snyder appointed the following Committee on Civic Affairs:

Samuel E. Duff, Chairman;
K. H. Talbot, Vice Chairman;
George M. Lehman,
J. H. Minton,
George W. Nichols,
Walter Spellmire.

On March 4th, a full meeting of the Committee was held and the following resolution adopted:

"Resolved, That the Civic Affairs Committee report to the Board of Direction their unanimous opinion that the relationship of the Engineers' Society of Western Pennsylvania to public affairs properly implies constructive suggestion relative to and impartial criticism of legislation and the expenditure of public funds involving engineering principles and practice. To this end the Committee will maintain a watchful attitude toward legislation and public expenditure with the purpose of bringing to the attention of the Board such matters as appear worthy of consideration."

On March 16th, the Committee conferred with Wm. McClurg Donley, Road Commissioner of Allegheny County, relative to the road improvement program for the year. Learning that the work was entirely suspended on account of freight embargo on road making material imposed by the U. S. Government as a war measure, the Committee recommended that the Engineers' Society join the County Commissioners in representations through the Pennsylvania State Highway Commissioner to the

Secretary of the U. S. Department of Agriculture showing the necessity for immediate improvement of certain roads in order to relieve railroad congestion by means of short haul motor truck traffic.

At about the same time the Committee made a study of the report of Mr. E. K. Morse, Transit Commissioner of the City of Pittsburgh, and after conference with Mr. Morse, recommended to the Board of Direction that formal public endorsement be made of the Commissioner's recommendations on widening of streets and the regulation of automobile parking.

The suggestions of the Committee were approved by the Board of Direction, and a letter addressed to the Mayor and Council of Pittsburgh, as follows:

"In accordance with the Civic Affairs Committee report, the Board of Direction approves the constructive form of the Transit Commissioner's Report and while temporaily reserving judgment on those recommendations which are not possible of immediate fulfillment, heartily endorses those in regard to street widening and parking regulations as necessary to the maintenance and increase in efficiency of this community for the conduct of the war and during the future, and respectfully urge that they be carried out with the greatest possible speed."

This organization of twelve hundred technically trained engineers and executives desires to render all possible support to the executive and legislative branches of the local government in a spirit of service to the community.

On September 17th, the Civic Affairs Committee called the attention of the Board of Direction to the proposed appropriation by the City of Pittsburgh and Allegheny County of $40,000.00 for a housing survey of the Pittsburgh District, and recommended that the project receive the formal endorsement of the Society, suggesting that letters be addressed to the City and County authorities, "Pointing out the advisability of using as a basis for a study of the housing problem the very complete and accurate data obtained by the Transit Commissioner as to the place of residence of the employes of large corporations, extended by new studies to be made by the Commissioner to cover new conditions," and "calling the attention of the authorities to the evident saving in time and expense certain to be obtained if the housing survey is made under the direction of the Transit Commissioner and by engineers familiar by residence in this community with the unusual problems involved in housing and transportation arising from the topograhpic and meteorological conditions of the territory involved."

During the month of December, 1918, the communications to the Society from the Civic Club of Allegheny County proposing certain legislation empowering second class cities to establish zoning regulations and to regulate the height and character of buildings was referred to the Civic Affairs Committee. Since any activity initiated in this matter would have to be maintained during the coming session of the General Assembly

of Pennsylvania and, therefore, beyond the life of the present Civic Affairs Committee, the papers were returned to the Board without action.

In reviewing this the first year of formal activity of the Engineers' Society in public affairs, we believe it proper to point out that war conditions practically stopped local initiative on public work. The vast War activities of this district were under the control of the Federal Government, and could not properly be discussed by the Society.

A large part of our membership was engaged in personal service in the Army and Navy and in many other departments of the Government, to which they gave their best efforts in the quiet loyal spirit characteristic of engineers. Your Civic Affairs Committee was itself greatly weakened by the entrance of its Vice Chairman, into military service about the middle of the year, and the absence from the city of other members almost continuously.

As a result of the year's experience, your Committee is certain that the Engineers' Society can be of great benefit to the community by constructive criticism of such public affairs as depend largely upon technical knowledge for their successful administration, and express the hope that future committees may be able to accomplish much more than we were able to do.

Respectfully submitted,

SAMUEL E. DUFF,
Chairman, Civic Affairs Committee.

Report of Finance Committee

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

The books of the Society have been audited by the Finance Committee every month during the last year and found in good order. A special audit, covering the period to July 1, was made by Ernst & Ernst, expert accountants, and the books found correct. In September Ernst & Ernst were again called into consultation with a view of improving our method of accounting and rearranging our monthly financial statement. In cooperation with the secretary they worked out new methods that simplified our records. All essential records formerly kept in three books were consolidated in one book well adapted to the purpose. Old form of checks was discarded and a new form of voucher check was substituted. These changes will facilitate the work of the secretary and of the finance committee and will lighten the labor of an annual audit of our books.

A close check has been kept during the last year on members becoming delinquent with their dues, and at intervals the Finance Committee has presented a few names to the Board of Direction with a request that they

be dropped from the membership rolls, in accordance with our By Laws, if after formal notice to such members, their dues remained unpaid after a set date. We are glad to report, however, that in the majority of cases the delinquent dues were paid.

Respectfully submitted for the Finance Committee.

E. W. PITTMAN, *Chairman.*

Report of Treasurer

To Board of Direction,
Engineers' Society of Western Pennsylvania.

Your Treasurer begs to submit the following financial report of the Society for the year ending December 31, 1918:

RECEIPTS

Dues 1919	$ 27.50
1918	9,532.12
1917	498.75
1916	160.50
1915	100.75
1914	42.50
1913	10.00
Total dues	$10,372.12
Entrance fees	$ 360.00
Advertising	1,260.32
Proceedings	618.63
Society pins	45.00
Smoker receipts	513.00
Interest	939.91
Miscellaneous	6.17
Boat excursion	147.00
Total receipts	$14,262.15

EXPENDITURES

Administration	$ 4,059.02
Entertainment Committee	1,235.99
House Committee	3,525.03
Library	73.43
General Society	1,625.94
Civil Section	185.07
Mechanical Section	112.08
M. & M. Section	53.69
Proceedings	3,115.69
Membership Committee	38.00
Miscellaneous	2.80
Total expenditures	$14,026.74

INVESTMENTS

One	$1,000 Butler Water Co. 5% Bond No. 9, matures September 2, 1931	$ 1,025.00
Two	$1,000 Connellsville Water Co. 5% Bonds Nos. 317 and 318, maturing October 1, 1930	2,020.00
Two	$1,000 Portsmouth Berkley & Suffolk Water Co. 5% Bonds, Nos. 465-466 maturing Nov. 1, 1944	2,000.00
Two	$1,000 Jamison Coal & Coke Co. 5% Bonds Nos. 1502 and 1503, maturing Nov. 1, 1931	2,000.00
Two	$1,000 Union Steel Co. 5% Bonds Nos. 36642-36643 maturing Dec. 1, 1952	2,090.00
Two	$1,000 Pennsylvania Railroad Co. 4½% Bonds Nos. 27320-27321, maturing August 1, 1960	2,070.00
Three	$1,000 Jones & Laughlin Steel Co. 5% Bonds Nos. 3020-3021-3022, maturing May 1, 1931	2,997.92
One	$1,000 U. S. Liberty Bond 4¼% No. 54437, maturing September 15, 1928	1,000.00
	Total fifteen bonds	$15,202.92

ASSETS

	Dec. 31, 1917	Dec. 31, 1918
Building Fund		
Bond	$ 1,025.00	
Cash (Fidelity T. & T. Co.)	586.37	
Permanent Fund		
Bonds	13,177.92	15,202.92
Cash (Fidelity T. & T. Co.)	473.34	374.71
Reserve Fund		
Cash (Fidelity T. & T. Co.)	2,500.00	2,500.00
General Fund		
Cash (Diamond National Bank)	311.42	231.83
	$18,074.05	$18,309.46
Increase during 1918	235.41	
	$18,309.46	$18,309.46

It will be noticed that even financially the Society held its own. Practically all the bills are paid and there is an increase of $235.41 in the assets in spite of the adverse conditions which prevailed last year. We dare not forget that we carried 73 patriots on our membership list free and that our beautiful headquarters were also kept open in the evenings, so as to be a real home for all of us. The further fact that the reserve fund did not have to be disturbed speaks well for the business methods of our Secretary.

The purchase of one $1,000 Liberty Bond of the third issue was authorized by the Board of Direction, also the transfer of the Building Fund to the Permanent Fund. There is still a question as to the market

value of the Water Company's bonds, but since the Society receives interest based on par and since the bonds are reported to be steadily increasing in value, no better course was left open than to list them at par as in the past.

Respectfully submitted,

A. STUCKI, *Treasurer.*

Report of One-Hundred-Foot Standard Committee

To Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

Your committee, appointed to install a bench standard in the City-County Building, begs leave to report that no progress has been made during the past year.

The Committee considered that this work was not of such an essential need as to be required during the period of the war. The room in which the bench standard is to be installed has been finished. The wall brackets have been cast, the rod has been furnished and practically the complete plans of the installation have been approved by your committee.

We hope to complete this work during the coming year.

Respectfully submitted,

LOUIS P. BLUM, Chairman;
N. S. SPRAGUE,
J. G. CHALFANT,
Committee on One-Hundred-Foot Standard.

Report of Westinghouse Memorial Committee

At the Society's regular monthly meeting of November 19, 1918, the Westinghouse Memorial Committee presented a report of progress, and the following resolution was unanimously adopted:

"RESOLVED, That the report of progress of the Westinghouse Memorial Committee, dated November 19, 1918, be received and filed, that the Committee be continued; and that the proper officers of the Engineers' Society of Western Pennsylvania be hereby authorized and instructed, to acquire the Westinghouse Property, and to convey the same to the City of Pittsburgh for a public park and memorial to the late George Westinghouse, without financially involving the Society, as recommended by the Committee."

The same evening, immediately following the above action, a meeting of the Board of Direction was held and the following resolution was unanimously adopted:

"RESOLVED, That pursuant to the above resolution of the Society the Board of Direction, hereby designates the President, William Emery Snyder, attorney in fact for the duly authorized officers of the Engineers' Society of Western Pennsylvania and does hereby empower and direct him to execute the deed of the Society conveying the residence property of the late George Westinghouse to the City of Pittsburgh, and to give to said deed the same force and effect as it would have if executed by all of said authorized officers of the Engineers' Society of Western Pennsylvania."

On November 18, 1918, the Board of Direction and the Memorial Committee met the Mayor and the City Council in the former's office and discussed informally the project in a way apparently satisfactory to all concerned. In accordance with the general understanding thus arrived at, Mr. George E. Shaw, of Reed, Smith, Shaw & Beale, prepared the deed from Mr. George Westinghouse, Jr. to the Society. It was executed on November 30, 1918, to the latter's attorney, Mr. Grosvenor Calkins of Boston, and the consideration was paid as previously arranged.

In consulation with Mr. Stephen Stone, City Attorney, Mr. Shaw also prepared the deed of dedication of the Society to the City of Pittsburgh, which was duly executed November 30, 1918, and embodied in the following ordinance adopted by City Council and approved by Mayor E. V. Babcock, December 16, 1918.

Your Committee desire to express their sincere appreciation of the prompt and hearty cooperation of all concerned.

The ordinance requires that the property conveyed be perpetually maintained in good condition as a public park and be known as *Westinghouse Park.* Also that the homestead building, known as "Solitude," now upon the premises shall be removed by the City within six months after December 19, 1918.

The Engineers' Society reserves the right to erect on the property a suitable memorial, the character, design and location of which is to be subject to the approval of the City of Pittsburgh.

In submitting this report, we recommend that the present Committee be discharged.

Respectfully submitted,

GEORGE S. DAVISON, Chairman;
JULIAN KENNEDY,
EDW. B. TAYLOR,
W. LUCIEN SCAIFE.

On motion, the report and recommendation therein contained was adopted and the Committee discharged, with the thanks of the Society for their signally successful work.

Special Committee on Training of Women for Technical Positions

Your "Special Committee on Training of Women for Technical Positions" was appointed pursuant to the receipt of resolutions adopted at a joint meeting of the Detroit Section of the American Society of Mechanical Engineers and the Detroit Engineering Society. These resolutions are as follows:

WHEREAS, The demands of the country for men and means to fight the war have resulted in a deficiency of skilled workers in the trades and professions; and

WHEREAS, The women of this country could with a short period of training fit themselves to fill these positions, as women have done in other countries at war; and

WHEREAS, Among the things which women could do advantageously are drafting and tracing, inspection and testing of materials both physically and chemically; therefore

RESOLVED, That the universities, colleges and technical schools throughout the land be asked to consider the question of meeting this demand by providing special courses of instruction open to women students qualified to pursue such courses; and further

RESOLVED, That employers who could use such skilled help exert their influence with their universities, colleges and technical schools, and cooperate with them in developing and making available a great body of intellingent and adaptable women who are as eager and willing to serve their country as their brothers.

THEREBY bringing about not only increased effectiveness in fighting the war, but also a greater mutual respect and saner relationship of our men and women.

The emergency which called forth these resolutions has passed and your Committee begs to report that demand in the Pittsburgh district for women to serve as inspectors, draftsmen and tracers was not marked during the period of war, and at the present time the demand has practically ceased.

Certain of the larger engineering organizations, as the Westinghouse Companies, replaced men by women as draftsmen and inspectors, training such recruits in their own organization.

So far as your Committee is aware, no requests were made by such organizations for the training of women by outside local agencies, such as the engineering schools of this district.

The members of the Engineers' Society of Western Pennsylvania were asked, through the Monthly Bulletin of September 17, 1918, to notify the Secretary of the Society, if they needed the assistance of women trained for technical work. No requests were received.

Of the three institutions in Pittsburgh where technical training is regularly offered to students, both men and women, two, the University of Pittsburgh and Duquesne University provided no special courses for women which would prepare them for technical engineering work. At the Carnegie Institute of Technology, special war courses for women were offered in tracing, general mechanical drawing, the chemistry of iron and steel and the inspection of materials.

Wide publicity was given these courses, through the courtesy and active cooperation of the Employers Association of Pittsburgh. But few candidates presented themselves for the chemistry and inspection courses and they were not given. Two six-weeks' courses in tracing and two 12-weeks' courses in mechanical drawing were given. Thirty-three women completed the first and forty the second of these courses. All the graduates were able to secure positions at once and the salaries received ranged from $60.00 to $105.00 per month.

It would appear that women have "made good" in drafting rooms and laboratories where the qualities of accuracy, neatness and attention to detail are required and they will doubtless be able to maintain their place in the fields mentioned above.

In view of the fact that the problem of the proper qualifications and training which candidates for an engineering career should possess, is now being discussed by engineering societies and schools as never before, your Committee respectfully suggests that the training of women for technical positions might properly be given a place upon any program of training for engineering service which may come before this Society.

Respectfully submitted,

John A. Hunter,
Francis Tyson,
William E. Mott, Chairman.

Report of Civil Section

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

I beg to submit the report of work done by the Civil Section during the year 1918.

Four regular meetings of the Section were held during the year. The average attendance at these meetings was 69, the maximum being 103 at the January meeting and May meeting, and the minimum 20 at the March meeting.

An average of five participated in the discussion of the several papers presented. The papers presented during the year were:

January meeting—"The Flat Slab System"—A Topical Discussion—By C. A. P. Turner, Consulting Engineer, Minneapolis, Minn.; A. E. Lindau, Gen. Mgr. Sales, Corrugated Bar Co., Buffalo, N. Y.; T. L. Condron, Cons. Engr., Chicago, Ill., and Edward Godfrey, Struct. Engr., Bobt. W. Hunt & Co., Pittsburgh, Pa.

March meeting—"The Training of Mechanics for Maintenance and Repair of Air Plane and Air Plane Engines"—By Prof. J. C. Sproule, Assoc. Prof., Mechanical Engineering, Carnegie Institute of Technology;

Prof. A. H. Blaisdell, Instructor, Dept. Mechanical Engineering, Carnegie Institute of Technology, and Lieut. W. A. Hammond, Chf. Instructor, Airplanes and Airplane Engines, C. I. T.

November meeting—"New and Little Known Methods of Calculation of Beams and Girders and Arches"—By James S. Martin, Engr., Pittsburgh Railways Co.

Respectfully submitted,

George H. Danforth, *Chairman.*

Report of Mechanical Section

To the Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

I beg to submit report of the Mechanical Section during the year 1918.

Three regular meetings of the Section were held during the year. The average attendance at these meetings was 44, the maximum being 98 at the December 3rd meeting and the minimum 12 at the April 9th meeting.

An average of seven participated in the discussion of the several papers presented. The papers presented during the year were:

February meeting—"Electricity as a Substitute for Natural Gas for Heating Purposes," was presented by Frank Thornton, Jr., Engineer, Electric Heating Dept., Westinghouse Elec. & Mfg. Co.

April meeting—"The Design of Governors with Special Reference to Small Diesel Engines," by Arthur B. Lakey, Associate, Albert Kingsbury, Engineer, Pittsburgh.

December meeting—"The Design of Heating Furnaces From a Practical Standpoint," by George J. Hagan, Gen. Mgr., George J. Hagan Co., Pittsburgh.

Respectfully submitted,

Albert Kingsbury, *Chairman.*

Report of Metallurgical and Mining Section

To Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

I beg to submit report of the Metallurgical & Mining Section during the year 1918.

One regular meeting of the Section was held during the year. The attendance was 101 at the meeting held January 22, 1918. Twelve men

participated in the discussion of the paper presented, which was "Pulverized Coal in Metallurgical Furnaces as a Substitute for Natural Gas," by W. O. Renkin, Mgr., Engineering Dept., Quigley Furnace Specialties Co., New York City.

Respectfully submitted,

FREDERIC CRABTREE, *Chairman.*

Report of Tellers

To the Members of the
Engineers' Society of Western Penna.

Dear Sirs:

The undersigned Tellers publicly canvassed the ballots in the Annual Election of Officers of the Society at noon, Tuesday, January 21, 1919, and beg to report the following results:

Ballots received	304	
Irregular ballots	21	
Total	325	
For President—George H. Neilson		283
For Vice President—George H. Danforth		278
For Treasurer—A. Stucki		277
For Directors	Fred C. Schatz	282
	W. B. Spellmire	277

Respectfully submitted,

L. C. FROHRIEB,
L. F. W. HILDNER,
M. F. NEWMAN,
Tellers.

The President thereupon declared the following men elected:

For President	George H. Neilson
For Vice President	George H. Danforth
For Treasurer	A. Stucki
For Directors	W. B. Spellmire
	Fred C. Schatz

Mr. Hoerr requested Past Presidents George S. Davison and W. L. Scaife to escort the President elect, Mr. George H. Neilson to the chair, who upon assuming the chair, addressed the Society as follows:

"I thank the Society for this honor, which I really consider an honor and a very great one. I will not detain you by asking you to listen to very much, but I would like to speak of one thing. The last year has been,

considering the disadvantage under which the Society has worked, very successful, and the coming year, 1919, should be even more so. I urge the membership not to depend upon the officers to make the year a success. It depends upon every one of us. Some days ago I was asked to interview a member who was talking of resigning, I asked him why he thought of doing so and he said that he didn't get anything out of the Society. I replied, 'Naturally, you never come to it. You can't expect the Society to go to you. If you wish to get anything out of it, there is lots here to get out and it is up to you to come and get it.' So, it is up to all of us to do our best and I ask for the thorough cooperation of the members of the Society to assist in making this our banner year."

No further business coming before the Society, the address of the retiring President was presented by Mr. A. L. Hoerr, due to the absence of Mr. Snyder on account of illness.

Written discussion was received from: Mr. Palmer Collins, Donner Steel Co., Buffalo, N. Y.; Mr. John A. Hunter, Steam and Sanitary Engr., American Sheet & Tin Plate Co., and Mr. J. C. Hobbs, Asst. to Supt. of Power Stations, Duquesne Light Co.

The ensuing discussion was participated in by: Mr. J. H. Dalley, Locomotive Pulverized Fuel Co., 30 Church St., New York; Mr. W. E. Moore, Pres., W. E. Moore & Co., and Mr. A. L. Hoerr, Chf. Engr., National Tube Co., McKeesport, Pa.

On motion the meeting adjourned at 10:38 P. M.

K. F. Treschow, *Secretary.*

METALLURGICAL AND MINING SECTION

The Annual Meeting of the Metallurgical & Mining Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade, Tuesday, January 28, at 8:10 P. M., Chairman Frederic Crabtree presiding, 74 members and visitors being present.

The Minutes of the last Annual meeting held January 29, 1918, were read and approved.

The annual report of the chairman was read by the Secretary.

The report of the Nominating Committee was presented by Mr. C. F. W. Rys, Chairman:

To Officers and Members of Metallurgical & Mining Section,
Engineers' Society of Western Penna.

Dear Sirs:

Your Nominating Committee have selected the following names as their recommendation for officers of the Metallurgical & Mining Section for the ensuing year:

George L. Norris..Chairman
E. J. Taylor..Vice Chairman
W. E. Fohl
F. A. McDonald
J. S. Unger ....Directors
Floyd Rose
G. P. McNiff

Respectfully submitted,

Nominating Committee,
C. F. W. Rys, Chairman;
H. P. Tiemann.
W. L. Affelder,

On motion nominations were closed and the Secretary was requested to cast a unanimous ballot in favor of the election of the officers named, who were thereupon duly declared elected.

On motion the meeting adjourned at 8:30 P. M.

K. F. Treschow, *Secretary.*

METALLURGICAL AND MINING SECTION

Bi-Monthly Meeting

The regular Bi-monthly Meeting of the Metallurgical & Mining Section of the Society was held in the Society Rooms, Union Arcade, Tuesday, January 28, 1919, at 8:30 P. M., chairman George L. Norris presiding, 74 members and visitors being present.

The Minutes of the last regular meeting held January 29, 1918, were read and approved.

No further business coming before the Section the paper of the evening on "Some Considerations With Regard to Fuel Gas" was presented by Prof. Crabtree, retiring chairman.

Written discussion was received from: Mr. Carroll Miller, Gen. Mgr., Philadelphia Company, and Mr. A. E. Blake, Sales Engr., Surface Combustion Co.

The ensuing discussion was participated in by: Mr. G. L. Norris, Met. Engr., American Vanadium Co.; Mr. B. M. Herr, Dist. Sales Mgr., Edward Valve Mfg. Co., and Mr. J. H. Taussig, United Gas & Improvement Co., Philadelphia, Pa., and the author.

On motion the meeting adjourned at 9:48 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Tuesday, February 4, 1919, at 4:30 P. M. Mr. W. C. Hawley, Vice President presiding in the absence of Mr. Neilson, President, Messrs. Kingsbury, Danforth, Hoerr, Schatz, Spellmire, Pittman and the Secretary being present.

The Minutes of the last regular meeting held January 7th were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Anderson, Robert
Elder, David
Kelley, Henry D.
Offutt, John William
Stephany, Erwin John

ASSOCIATE MEMBER

Kronfeld, Gus L. S.

JUNIOR

Abramovitz, Hymen Louis

The following applications for membership were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Heckman, Charles J.
McLaughlin, Thomas J.
Neeld, Jr., Almos Davidson
Steele, Donald Alexander

JUNIORS

Rose, Hudson Brooks

Following applications were received in answer to invitations sent to American Chemical Society to join our Society:

Austin, W. M.	Kemery, Philo
Bissonette, E. M.	Koch, J. A.
Churchill, J. B.	Montgomery, F. J.
Evans, T. R.	Peirce, Joseph Otis
Johnson, Chas. Morris	Reed, Robert R.
Jones, George W.	Semple, J. B.
Weidlein, E. R.	

The Secretary presented letters of resignation from the following gentlemen, which after discussion, were accepted:

Follansbee, M. A. .... Joined Dec., 1912
Zortman, C. E. .... Joined Mar., 1917

The Secretary reported the death of the following gentlemen:

Bliss, H. N. .... Died Dec. 13, 1918
Ernst, Alfred .... Died Dec. 13, 1918

The report of the Secretary showing the financial condition of the Society December 31, 1918, having been previously audited by the Finance Committee, was approved.

Mr. E. W. Pittman, Chairman of the Finance Committee, reported that no meeting of the Committee had been held during January. The Secretary's financial statement of December 31st, was checked and approved by the Chairman.

No other reports were submitted on account of the recent appointment of the new Chairman for the year and no work having been done since their election.

The Secretary presented a report on behalf of Mr. George H. Neilson, President, stating that the Chairmen for all committees had been appointed for the ensuing year.

The Secretary retired from the meeting while the election of a secretary for the ensuing year was considered. Kenneth F. Treschow was re-elected Secretary of the Society at an increase in salary of $25.00.

At the request of the Secretary, Miss Harper, stenographer in the Society's office, received an increase of $10.00 per month in salary.

The Secretary read a letter from Mr. O. K. Davis, Secretary of the Sixth National Foreign Trade Convention of the National Foreign Trade Council to be held in Chicago, April 24th, 25th and 26th, asking that our Society be represented by a delegation of four to six members.

Mr. Danforth stated that he thought he knew of one or two members who would be in Chicago on these dates and agreed to see them in regard to acting as representatives of the Society at the Convention.

The Secretary presented the following report of Mr. S. A. Taylor, who was appointed by President Snyder to represent the Society at the Conference on Industrial Safety Codes held at the Bureau of Standards, Washington, D. C.:

January 18, 1919.

Mr. K. F. Treschow, Secretary,
Engineers' Society of Western Penna.

Dear Sir:

In reference to the meeting relative to Safety Codes, held in Washington, D. C., January 15, 1919, to which I received the appointment of representative for our Society, I wish to report as follows, to wit:

I attended the meeting on the afternoon of the day, having been detained at the U. S. Fuel Administration in the morning. I am enclosing a copy of the tentative program, which was carried out partially.

The most of the men on the program, at least for the morning session were heard. The general discussion took place of the afternoon program, and some of the men who were on for the morning were not heard until the afternoon; and not nearly all on the afternoon program were heard. The discussion was very intensive, and was not confined to the Engineering Societies or to the members of the staff of the Bureau of Standards; but was participated in by the Safety men of several large industries, and Safety and compensation Insurance men, who in many cases seemed to be rather jealous of the work done by the Committee of the National Engineering bodies as ignoring and trespassing on their respective prerogatives. The discussion was, as a consequence, very interesting and instructive.

However, the discussion, as a general thing, was aimed at five questions, propounded by the Bureau of Standards and written out on a blackboard; and were as follows:

Shall the Bureau of Standards attempt to prepare, with the cooperation of all the interests concerned, a National Standard of Safety Codes as suggested?

If the Bureau does not do it, what agency will take its place?

If the Bureau goes forward in the work, will it have the cooperation of all the interests concerned?

Can it have a representative Conference Committee, of say 25 or 50 persons, to represent all of the interests affected, with smaller committee for particular codes?

Is the proposal to reorganize the American Engineering Standards Committee, and obtain its approval of the Codes, approved by this conference?

After a prolonged debate, which did not show a very unanimous opinion, the following motion was duly made and carried.

The motion was, that the Bureau of Standards undertake to select a committee from the various industries interested, for the purpose of promulgating a Program of Procedure, and when this is done to call another conference for discussion and ratification, after which the conference adjourned *sine die.*

Respectfully submitted,
(Signed) S. A. Taylor.

It was moved and carried that the Secretary be requested to write Mr. Taylor, thanking him on behalf of the Board of Direction for his very complete report on the Conference.

Mr. Danforth brought up the matter of the proposed license law for architects and its several phases were discussed at some length at the meeting.

On motion the meeting adjourned at 5:30 P. M.

K. F. Treschow, *Secretary.*

MECHANICAL SECTION

The Annual Meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, February 4, 1919, at 8:10 P. M., Chairman Albert Kingsbury presiding, 62 members and visitors being present.

The Minutes of the last Annual Meeting held February 5, 1918, were read and approved.

The annual report of the Chairman was read by the Secretary.

The report of the Nominating Committee was presented as follows:

Officers and Members Mechanical Section,
Engineers' Society of Western Pennsylvania.

Dear Sirs:

Your Nominating Committee have selected the following gentlemen for officers for the Mechanical Section for the ensuing year:

L. C. Frohrieb..........Chairman
J. C. Hobbs..........Vice Chairman

George T. Ladd
W. K. Frank
M. R. Maclean
Dexter Edge
C. E. Skinner
..........Directors

Respectfully submitted,
E. D. Leland, Chairman;
J. A. Hunter,
C. D. Terry,
Nominating Committee.

On motion nominations were closed and the Secretary was instructed to cast a unanimous ballot in favor of the officers named and they were thereupon declared elected.

On motion the meeting adjourned at 8:45 P. M.

K. F. Treschow, *Secretary.*

Mechanical Section

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, February 4, 1919, at 8:45 P. M. Chairman L. C. Frohrieb presiding, 62 members and visitors being present.

The Minutes of the last regular meeting held December 3, 1918, were read and approved.

There being no further business before the Section, Mr. Albert Kingsbury presented his retiring address on "Experiments in Lubrication."

The ensuing discussion was participated in by: Mr. F. L. Egan, Carnegie Steel Co., Pittsburgh, Pa.; Mr. J. F. Craven, Craven Laboratories, Pittsburgh, Pa.; Mr. B. F. Groat, Cons. Engr., Pittsburgh, Pa., and the author.

There being no further business, on motion the meeting adjourned at 10:30 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 374th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, February 18, 1919, at 8:15 P. M. President George L. Neilson presiding, 260 members and visitors being present.

The Minutes of the last regular meeting held December 17, 1918, were read and approved.

The Board of Direction reported the election of five applicants to the grade of Member, one to the grade of Associate Member and one to the grade of Junior; the two latter being members of the A. S. M. E. and A. C. S. respectively, and the receipt of eighteen applications for membership, thirteen of these having been received from local members of the American Chemical Society in answer to invitations asking them to join our Society.

There being no further business before the Society, the paper of the evening was presented by Dr. C. E. K. Mees, Director, Research Laboratories, Eastman Kodak Co., Rochester, N. Y., on "The Camera In the War."

It was moved and carried that a vote of thanks be extended to Dr. Mees for his very interesting and valuable paper of the evening.

On motion the meeting adjourned at 9:43 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 375th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, March 18, 1919, at 8:15 P. M. Vice President W. C. Hawley presiding in the absence of President Neilson, 123 members and visitors being present.

The Minutes of the last regular meeting held February 18th, were read and approved.

The Board of Direction reported the election of seventeen applicants to the grade of Member and one to the grade of Junior, thirteen of these having been received from the American Chemical Society local members in answer to our invitation to join the Society. Ten applications received for membership, eight from the American Chemical Society. Receipt of one application for transfer to higher grade and one for reinstatement to membership in the Society.

There being no further business before the Society, the paper of the evening on "Steel for Ordnance Manufacture in England and France," was presented by Major F. F. McIntosh, Associate Chief Metallurgist, Technical Staff, Ordnance Dept., U. S. Army, Washington, D. C.

The ensuing discussion was participated in by: Prof. Frederic Crabtree, Professor of Metallurgy, Carnegie Inst. of Technology; Mr. George Chamberlain, Edgar Thomson Works, Carnegie Steel Co., Braddock, Pa.; Mr. Philo Kemery, Supt. O. H. & Crucible Dept., Crescent Works, Crucible Steel Co. of America; Mr. George L. Norris Metallurgical Engr., American Vanadium Co.; Mr. G. P. McNiff, Metallurgical Engr., National Tube Co., and the author.

Mr. H. D. James moved that a vote of thanks be tendered to Major McIntosh for his very interesting paper, which was carried unanimously.

On motion the meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, March 4th at 4:20 P. M., President George H. Neilson presiding, Messrs. Hoerr, Snyder, Danforth, Hawley, Pittman, Spellmire, Schatz, Frobrieb, Norris, Minton, Stucki and the Secretary being present.

The Minutes of the last meeting held February 4th, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

Members

Austin, W. M.
Bissonette, E. M.
Churchill, J. B.
Evans, T. R.
Heckmon, Charles J.
Johnson, C. Morris
Jones, George W.
Kemery, Philo
Koch, J. A.
McLaughlin, Thomas J.
Montgomery, F. J.
Neeld, Jr., Almos D.
Peirce, Joseph O.
Reed, Robert R.
Semple, J. B.
Steele, Donald A.
Weidlein, E. R.

Juniors

Rose, Hudson Brooks

The following applications for membership were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

Members

Blough, A.
Brown, W. D.
Darrin, Marc
Duggar, Jr., J. F.
Fieldner, A. C.
Fisher, Hervey Albert
Ford, Allen W.
Satler, Jr., Louis L.
Wharton, Joseph B.

Associate Members

Churchill, H. V.

Application for transfer to higher grade of membership was received from Albert V. Dolan, who after discussion was transferred to the grade of Member.

The Secretary read a letter from Mr. Dorsey A. Lyon asking to be reinstated to membership in the Society, whereupon the Secretary was authorized to replace his name on the Society Rolls.

The Secretary presented resignations from the following gentlemen and after discussion, they were ordered accepted:

H. H. Armstrong	Joined April,	1918
W. A. Cornelius	Joined Nov.,	1899
R. O. Rall	Joined March,	1916
W. C. Rott	Joined Sept.,	1905

The report of the Secretary showing the financial condition of the Society January 31, 1919, having been previously audited by the Finance Committee, was approved.

Mr. Danforth, Chairman of the Civic Affairs Committee, reported progress stating that he hoped to have his committee complete within the next few days.

Mr. Hawley, Chairman of the Entertainment Committee, reported that the committee has been appointed—W. C. Hawley, Chairman; Messrs. G. M. Baker, H. D. James, E. E. Lanpher, H. D. Wilson.

No meeting has been held, but a meeting will be called within a few days. It is proposed to hold a Smoker at an early date, and we also have two or three excursions in view which will be considered. With the termination of war activities, it is probable that we will be permitted to visit some of the plants to which we were unable to obtain admission during the last two years. The Committee will be pleased to have suggestions of members of the Board of Direction as to excursions or desirable entertainments which could be arranged for the members of the Society.

Mr. Pittman, Chairman of the Finance Committee, reported that the Secretary's financial statement for January had been checked and approved. The receipts for January, 1919, are about $800.00 more than for the same month last year and as compared with January, 1917, which was a normal year, the receipts show an increase of about $400.00.

Mr. Schatz, Chairman of the House Committee, reported the following evening attendance for February:

First week	21
Second week	11
Third week	23
Fourth week	12
Total	67

Mr. Spellmire, Chairman of the Publication Committee, reported progress, stating that he hoped to have his committee complete within the next few days.

A committee consisting of Mr. Richard Khuen, chairman; W. A. Weldin and J. D. Stevenson, appointed by the local association of the American Society of Civil Engineers, appeared before the Board of Direction to take up the matter of co-operation among all engineering organizations located in Pittsburgh. Mr. Khuen addressed the Board stating that at a dinner held last Friday evening the committee had been appointed to suggest to the Board that the Engineers' Society of Western Pennsylvania call a meeting of delegates from all engineering organizations in Pittsburgh to discuss ways and means for a closer and more effective relationship among these organizations and the Engineers' Society. Mr. Khuen pointed out that the local association members felt that the Engineers' Society should be the one to take the initial step as it was the oldest organization in the district.

Mr. Neilson thanked the Committee for the interest shown in coming before the Board and the Committee then retired from the meeting.

After discussion it was moved and carried that the President be authorized to appoint a committee of as many as he might think necessary to confer with similar committees from other local organizations at a meeting, the time and place to be selected later, to take up the matter of co-operation and the methods to be used to effect a closer and more beneficial relationship among these organizations.

The Secretary read a letter from Mr. George S. Davison, former Chairman of the Westinghouse Memorial Committee as follows:

Jan. 22, 1919.

Mr. George H. Neilson, Pres.,
Engineers' Society of Western Penna.

Dear Sir:

Referring further to the Report of the Westinghouse Memorial Committee, I would state that it is the idea of the members of the old Committee that the Board of Direction at some time in the future appoint a committee consisting of both members and non-members of the Society to form a Committee to consider plans for a memorial on the Westinghouse property and for the raising of funds for paying the same. The idea of having non-members on this committeee would be for the purpose of placing a part, if not all, of the raising of the subscriptions upon such members of the committee.

We think there is plenty of time in which to take this matter up as we believe it is not an opportune time to solicit funds. We must get to another cycle of the World's business when men of means are having an income that they feel they can apply to objects of this kind.

The members of the old Committee will hold themselves in readiness to discuss this matter with the Board of Direction at any time the latter desires.

Yours truly,

(Signed) GEORGE S. DAVISON.

It was moved and carried that the President be authorized to appoint a committee as suggested.

The Secretary read a letter of resignation received from Mr. Robert Linton stating that in view of the fact that he would be obliged to be out of the city a large part of the time, he did not feel that he was justified in remaining a member of the Board of Direction. After discussion, it was moved and carried that Mr. Linton's resignation be accepted with regret.

The Secretary presented the following report from the Medal Awards Committee:

March 3, 1919.

Board of Direction,
Engineers' Society of Western Penna.

Dear Sirs:

Your committee has carefully considered the papers published in the Society "Proceedings" during 1918 and has unanimously agreed to award a silver medal to Mr. James S. Martin for his paper entitled "New or Little Known Methods of Calculation of Girders, Beams and Arches."

Your committee did not deem any of the papers of sufficient merit to warrant the awarding of a gold medal.

Yours sincerely,
(Signed) H. D. JAMES, Chairman,
Medal Awards Committee.

It was moved and carried that the report of the committee be approved as read.

Mr. Neilson brought up the matter of the proposed steel tower for a memorial to our soldiers, suggested by Mr. Henry Pennywitt, Local Forecaster of the U. S. Weather Bureau, and after discussion, the Secretary was requested to write Mr. Pennywitt stating that the Board was heartily in accord with his suggestion.

Mr. Danforth reported, in accordance with his suggestion at the last Board meeting, he found that Mr. A. H. Holliday, a member of the Society was to be in Chicago at the time of the Conference of the Sixth National Foreign Trade Convention of the National Foreign Trade Council to be held in Chicago, April 24, 25 and 26, and had asked him to attend the convention as a representative of the Society to which Mr. Holliday agreed.

The Secretary was requested to write Mr. Holliday expressing our appreciation of his courtesy in the matter.

Mr. Hawley presented the matter of a vacancy on the Public Service Commission caused by the death of Judge Harold H. McClure, suggesting that the Secretary be requested to write to Gov. W. C. Sproul stating that in the opinion of the Board of Direction of the Engineers' Society of Western Pennsylvania, this vacancy should be filled by an engineer. It was further suggested that a copy of this

letter be sent to the various engineering societies in the state with the request that they take similar action.

After discussion, it was moved and carried that action be taken as above suggested.

The meeting adjourned at 5:45 P. M.

K. F. TRESCHOW, Secretary.

MECHANICAL SECTION

Bi-Monthly Meeting

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Bldg., Tuesday, March 4 at 8:00 P. M. Chairman L. C. Frohrieb presiding, 64 members and visitors being present.

The Minutes of the last meeting held February 4 were read and approved.

There being no further business before the Section, the paper of the evening on "Steam Power Plants as Applied to Vehicles for Common Roads," was presented by Mr. F. L. Egan, Engr. of River Equipment, Carnegie Steel Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: Mr. George H. Danforth, Struct. Engr., Jones & Laughlin Steel Co.; Mr. F. C. Fair, Carnegie Inst. of Technology; Mr. John A. Ferguson, Sec'y-Engr., Building Code Committee, City of Pittsburgh; Mr. D. J. Fleming, H. Koppers Co.; Mr. L. C. Frohrieb, Secy., Federal Engineering Co.; Mr. E. W. Pittman, Mgr., John Eichleay Jr. Co.; Mr. W. B. Spellmire, Mgr., General Electric Co.; Mr. Fred Schatz, Supt., Buildings & Equipment, Jos Horne Co.; Mr. F. M. Van Deventer, Engineering Dept., National Tube Co., and the author.

On motion the meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, Secretary.

METALLURGICAL & MINING SECTION

Bi-Monthly Meeting

The regular bi-monthly meeting of the Metallurgical & Mining Section of the Engineers' Society of Western Pennsylvania was held in the Lecture Room, Carnegie Library, Tuesday evening, March 25, at 8:15 P. M. in joint session with the Pittsburgh Sections of the American Chemical Society and the American Electrochemical Society, Chairman George L. Norris presiding, 260 members and visitors being present.

The Minutes of the last meeting held January 28, 1919, were read and approved.

No further business coming before the Section, an address on "Gas, Smoke and Flame In This War and the Next," was given by Col. William H. Walker, Chemical Warfare Service, U. S. Army, Baltimore, Md.

There being no discussion, on motion the meeting adjourned at 10:30 P. M.

K. F. TRESCHOW, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade, Tuesday, April 1, 1919, at 4:20 P. M., Vice President W. C. Hawley presiding in the absence of Mr. Neilson, President. Messrs. Snyder, Stucki, Pittman, Minton, Spellmire, Hawley, Schatz, Danforth and the Secretary being present.

The Minutes of the last meeting held March 4th were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Blough, E.
Brown, W. D.
Darrin, Marc
Duggar, Jr., J. F.
Fieldner, A. C.
Fisher, Harvey Adelbert
Ford, Allen W.
Satler, Jr., Louis L.
Wharton, Joseph B.

ASSOCIATE MEMBER

Churchill, H. V.

The following applications for membership were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Dandridge, Edmund P.
Dewey, George R.
Baxter, James W.
Crellin, Edward W.
Iffarth, William C.

ASSOCIATE MEMBERS

Pyle, Clyde B.
Ilsen, Herman C.
Spencer E. R.

The Secretary read a letter of resignation from Mr. Kenneth Talbot, which after discussion was accepted.

Application for transfer to higher grade of membership was received from Mr. Levi Bird Duff, who was thereupon transferred to the grade of Member.

The report of the Secretary showing the financial condition of the Society February 28, 1919, having been previously audited by the Finance Committee, was approved.

A letter was read from Mr. A. N. Diehl, stating that due to the fact that he had been transferred to Duquesne, he would be unable to attend Board meetings and for this reason wished to resign from the Board of Direction. The Secretary was requested to write Mr. Diehl accepting his resignation with regret.

Mr. Danforth, Chairman of the Civic Affairs Committee, reported that his committee had in hand the matter of license bill proposed by the American Institute of Architects. He stated that the final bill had little change from the original rough draft, as explained by the President of the Pittsburgh Chapter, and expected to have a copy of the bill available in the near future.

Mr. Hawley, Chairman of the Entertainment Committee, advised that no meetings had been held but that a Smoker would be held at the Fort Pitt Hotel, Saturday evening, April 12, 1919. Two members originally appointed on the committee were unable to serve and Mr. Allen S. Davison was asked to serve. Another member will be appointed soon. A meeting of the Committee will be held in the near future to consider future activities.

Mr. Pittman, Chairman of the Finance Committee, reported that the financial statement of February 28th had been checked and approved. Receipts for this year to February 28th are about $800.00 in excess of the receipts for the same period last year. The new members of the Finance Committee are Mr. H. P. Smith and Mr. Clyde Taylor.

Mr. Schatz, Chairman of the House Committee, reported an evening attendance of 69 for the month of March.

He further stated that a letter had been received from the Commanding Officer of the U. S. Army General Hospital No. 24 at Parkview, Pa., in answer to our inquiry as to whether or not they would care to have some of our trade journals, *Literary Digest, Saturday Evening Posts* as they are removed from our tables, stating that they would be glad to receive them and thanking the Engineers' Society of Western Pennsylvania, as well as the House Committee, for their courtesy.

Mr. Spellmire, Chairman of the Publication Committee, reported verbally stating that his committee had now been appointed and a meeting would be held Saturday afternoon, April 12th.

The Secretary read a letter from Brig. Gen. Edgar Jadwin accepting our invitation to be a guest of the Society upon his return to the United States, but stated that he did not know at this time just when he would return.

The Secretary read a letter from Mr. H. D. James, as follows:

March 13, 1919.

Mr. K. F. Treschow, Secy.,
Engineers' Society of Western Penna.

Dear Sir:

I wish to make a suggestion in reference to our Society pin. I would like the Board of Direction to consider using several colors of enamel in the pin to designate the various grades of membership, such as is done in the American Institute of Electrical Engineers, and possibly some of the other national societies. A scheme of colors would not add to the expense of the pin, as the same die would be used. It, however, would add some distinction to those who are members of the Society and might stimulate a number who are in lower grades to ask for transfer.

In addition to the above, I would suggest that a specially colored pin be authorized for the use of past Presidents. This is done in the A. I. E. E. the designating color being white. It is the custom at the annual meeting for the Society to present one of these pins to the retiring President with an appropriate address, the whole formality being quite impressive, and it seems to me well worth while. I feel that any distinction of this kind which we can confer upon a man who has served as our President is very proper and would express in only a small measure the regard with which the Society should hold him.

Will you kindly bring this matter before the Board of Direction of the Society in the form of a suggestion.

Yours very truly,

(Signed) H. D. James.

It was moved and carried that this matter be referred to the Membership Committee.

The Secretary read a letter from Mr. H. H. McDevitt, Secretary to Governor Sproul in reply to our letter requesting that an engineer be appointed to fill the vacancy on the Public Service Commission, stating that the Governor would give the matter his careful attention.

Letter was read from Mr. F. H. Newell, Chairman of the Committee on Engineering Cooperation. After discussion it was moved and carried that the matter be referred to the Civic Affairs Committee with power to act.

The Secretary read a letter from Mr. J. Parke Channing, Chairman, Engineering Council. After discussion it was moved and carried that the letter be referred to the Civic Affairs Committee with power to act.

On motion the meeting adjourned at 5:05 P. M.

K. F. Treschow, *Secretary.*

CIVIL SECTION

Bi-Monthly Meeting

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday evening, April 1, 1919, at 8:17 P. M. Chairman J. H. Minton presiding, 47 members and visitors being present.

The Minutes of the last meeting held January 7, 1919, were read and approved.

No further business coming before the Section, the paper of the evening on "Construction of Steel Barges" was presented by Mr. Thomas Leach, Chief Engineer, Ferguson Steel & Iron Co., Buffalo, N. Y.

The ensuing discussion was participated in by: Mr. George H. Danforth, Struct. Engr., Jones & Laughlin Steel Co.; Mr. Samuel E. Duff, Consulting Engineer; Mr. V. B. Edwards, Supt. Warehouses, Dravo Contracting Co., Coraopolis, Pa.; Mr. H. K. Higgins, Asst. Engr., Aluminum Co. of America; Mr. James O. Jackson, Asst. Supt., Pittsburgh Des Moines Co.; Mr. J. H. Minton, Asst. Engr., Pennsylvania Lines; Mr. E. W. Pittman, Mgr., John Eichleay Jr. Co.,; Mr. E. R. Spencer, Thomas Spacing Machine Co., and the author.

It was moved, seconded and carried unanimously that a vote of thanks be extended to Mr. Leach for his very instructive and interesting paper.

On motion the meeting adjourned at 10:10 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 376th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Auditorium of the Chamber of Commerce, Tuesday, April 15, 1919, at 8:00 P. M., President George H. Neilson presiding, 334 members and visitors being present.

The Minutes of the last meeting held March 18, 1919, were read and approved.

The Board of Direction reported the election of nine applicants to the grade of Member and one to the grade of Associate Member, of this number eight were local members of the American Chemical Society. Eight applications received for membership, three from the A. C. S. and the transfer to higher grade of one applicant.

Mr. George H. Neilson, President, presented Mr. James S. Martin with a silver medal for the best paper presented during the year, paper

entitled "New and Little Known Methods of the Calculation of Beams, Girders and Arches."

No further business coming before the Society the paper of the evening on "Gas Warfare at the Front" was presented by Lieut. Col. B. C. Goss, Chief Gas Officer, First Army Corps, United States Army.

It was moved and carried that a vote of thanks be extended to Col. Goss for his very interesting and instructive address.

On motion the meeting adjourned at 10:04 P. M.

K. F. TRESCHOW, *Secretary.*

CIVIL SECTION

(Bi-Monthly Meeting)

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday evening, May 6, 1919, at 8:25 P. M. Chairman J. H. Minton presiding, 64 members and visitors being present.

The Minutes of the last meeting held April 1, 1919, were read and approved.

No further business coming before the Section, the paper of the evening on "Central Boiler Feed Water Service for Plants" was presented by Mr. S. H. McKee, Asst. Chief Engineer, Republic Iron & Steel Co., Youngstown, Ohio.

The ensuing discussion was participated in by: Mr. C. W. Crider, Supt. Boiler Room, Duquesne Light Co.; Mr. L. B. Duff, Civ. Eng., Empire Bldg.; Mr. Samuel E. Duff, Cons. Engr., Empire Bldg.; Mr. Ewerts; Mr. Max Hecht, Pittsburgh, Pa.; Mr. L. F. W. Hildner, Chf. Engr., Pittsburgh Bridge & Iron Wks.; Mr. J. C. Hobbs, Asst. to Supt., Power Stations, Duquesne Light Co.; Mr. B. A. Ludgate, P. & L. E. R. R. Co.; Mr. H. B. Mann, Eng., Dravo Doyle Co.; Mr. J. H. Minton, Asst. Engr., Pennsylvania Lines; Mr. R. M. Rush, Dist. Mgr., Kerr Turbine Co., and the author.

It was moved, seconded and carried unanimously that a vote of thanks be extended to Mr. McKee for his very excellent paper.

On motion the meeting adjourned at 9:45 P. M.

K. F. Treschow, *Secretary*.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade, Tuesday, May 12, 1919, at 4:15 P. M., President G. H. Neilson presiding, Messrs. Snyder, Hoerr, Hawley, Danforth, Barbour, Pittman, Stucki, Minton, Frohrieb and the Secretary being present.

The Minutes of the last regular meeting held April 1st, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Baxter, James W.
Crellin, Edward W.
Dandridge, Edmund P.
Dewey, George R.
Iffarth, William C.

ASSOCIATE MEMBERS

Pyle, Clyde B.
Ihen, Herman C.
Spencer, E. R.

The following applications for membership were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Bergen, George Thomas
Doane, N. D.
Fender, Willard Julius
Hecht, Max
Kilgour, David
Marsland, Roland
Morgan, Harold H.

ASSOCIATE MEMBERS

Polk, Robert Edmund
Gibson, Robert McDowell

JUNIOR

Ritts, Arch Verral

The following applications for reinstatement were presented by the Secretary who was authorized to place their names on the Society Rolls, as a Member.

B. A. Ludgate
R. H. Svenson

Applications for transfer to higher grade of membership were received from the following gentlemen and the Secretary was authorized to make the transfer as follows:

L. H. Carlinghouse....................Member
A. L. Lambie....................Associate Member

The Secretary presented letters of resignation from the following members, and after discussion, they were ordered accepted:

F. F. Bollinger	H. K. Hardcastle
A. W. Crouch	H. D. Hildebrand

The report of the Secretary showing the financial condition of the Society March 1, 1919, having been previously audited by the Finance Committee, was approved.

Committee Reports

Mr. Danforth, Chairman of the Civic Affairs Committee, reported verbally, stating that the Committee had held one meeting during the past month at which matters referred to the Committee by the Board of Direction had been taken up and disposed of. He further stated that the Committee now had up the matter of the Bond Issue to be voted on by the City some time in June, but that the Committee was not in a position to make any definite report at this time.

Mr. Hawley, Chairman of the Entertainment Committee, reported as follows: The Smoker at the Ft. Pitt Hotel April 12 was attended by 114. The receipts were $171.00, expenses $291.25, the deficit being $120.25. The program was one of the best we have had at any of our Smokers and the evening was thoroughly enjoyed by those present.

The Committee held a meeting April 29, at which various excursions were considered and arrangements made as follows:

Smoker at Ft. Pitt Hotel, Saturday evening, May 17, at which special entertainment will be motion pictures of mechanical apparatus of various kinds. This while not strictly technical, is expected to be of particular interest to engineers. There will also be a few comic films shown, and we expect a very enjoyable evening.

We are trying to arrange for an evening inspection tour of one of the large baking establishments in East Liberty, which will be held if possible during the latter part of this month.

On June 7 we are planning an excursion to Youngstown, Ohio, to visit the plant of the Republic Iron & Steel Co., where special attention will be paid to the central water station of the boiler feed supply system, which is to be discussed in the paper presented by Mr. McKee at this evening's meeting of the Civil Section of the Society.

Some time in June we expect to have another steamboat excursion and this will probably conclude our activities until Fall.

Mr. Pittman, Chairman of the Finance Committee, reported that the Financial statement of March 31, had been checked and approved by the Finance Committee.

Mr. Schatz, Chairman of the House Committee, reported evening attendance for the month of April as follows:

First week	17
Second week	19
Third week	20
Fourth week	24
Last four days	12
Total	92

Mr. Barbour, Chairman of the Membership Committee, reported verbally stating that due to the fact that he had been out of the City until the present time the Commitee had held no meetings, but that they expected to hold one in the near future.

Mr. Spellmire, Chairman of the Publication Committee, reported that two meetings of the Committee had been held, April 12 and May 5, and nineteen suggestions had been offered for papers for the ensuing year. The selection has been made and the schedule prepared, all of which is in the hands of the Secretary.

Mr. Hoerr, Chairman of the Special Committee on Cooperation of Engineering Organizations in Pittsburgh, reported verbally stating that two meetings of the Committee had been held during the past month and that he intended calling a joint meeting of delegates from the various National Societies in the near future to discuss the various points which had been brought up by members of our Committee. After the joint meeting, the Committee will report back to the Board of Direction for further action.

Mr. Neilson stated that due to the resignation of Mr. Robert Linton and Mr. A. N. Diehl from the Board of Direction there were two vacancies to be filled and asked for nominations. Mr. John A. Hunter, Steam and Sanitary Engineer, American Sheet & Tin Plate Co., and Mr. H. D. Wilson, President, Wilson, Snyder Mfg. Co., were nominated to fill these vacancies.

There being no further nominations, motion was made and carried unanimously that these two gentlemen be elected, and the Secretary was requested to notify them accordingly.

The Secretary read a letter addressed to the Board of Direction from Mr. Neilson, stating that owing to the fact that it was necessary for him to be in New York on the first Tuesday of each month, he would not be

able to attend Board meetings and asked the members whether or not some other day in the week would prove satisfactory to them.

Mr. Neilson stated that he did not feel that he could conscientiously continue as President of the Society and not attend the meetings and that unless another day than Tuesday was selected, he felt he should resign. After discussion, it was moved and carried that future meetings of the Board of Direction be held on the first Thursday of each month.

The Secretary presented the following report from Mr. S. A. Taylor in regard to the Safety meeting of the Bureau of Standards at Washington, D. C., January 15, 1919, which he attended as a delegate of our Society. A ballot to be filled out by the Secretary was also enclosed and after discussion, it was moved and carried that the Secretary be authorized to fill in the ballot in accordance with Mr. Taylor's suggestions. The Secretary was also requested to write Mr. Taylor notifying him of the action taken by the Board.

April 29, 1919.

Mr. K. F. Treschow, Secy.,

Engineers' Society of Western Penna.

Dear Sir:

Enclosed please find correspondence from Bureau of Standards, Washington, D. C., in reference to report of the Safety Meeting held in Washington, January 15, 1919, to which I was a delegate from the Society.

I am inclined to the opinion that Plan "B" will be the most effective, for the reason that I think all parties in interest will be better satisfied than if the same be handled by any one branch of the Government, for the following reasons:

1. That if one branch of the Government takes this up, there is likely to be more or less feeling engendered between departments.

2. Again, there is a growing feeling among business men that there is too much Government regulation or interference in business now, and this may only accentuate this feeling, and in the end render this scheme less effective.

3. Many lines of Safety endeavor are now organized among business concerns and technical associations, and it appears to me more genuine progress will be made if these same efforts can be given opportunity to continue, for by so doing they will take a greater interest in the work.

Yours very truly,

(Signed) S. A. Taylor.

The meeting adjourned at 5:25 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 377th regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, May 20, 1919, at 8:15 P. M., President George H. Neilson presiding, 67 members and visitors being present.

The Minutes of the last regular meeting held April 15th, were read and approved.

The Board of Direction reported the election of five members to the grade of Member and three to the grade of Associate Member and the receipt of ten applications for membership. Also two applications for transfer to higher grade and two for reinstatement.

There being no further business before the Society, the paper of the evening on "Notes on Heat Treatment of Steel" was presented by Mr. T. D. Lynch, Research Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

The ensuing discussion was participated in by: Mr. W. E. Moore, Pres., W. E. Moore & Co., Pittsburgh, Pa.; Mr. C. P. Miller, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.; Mr. George H. Neilson, V. P., Braeburn Steel Co., Braeburn, Pa.; Mr. C. M. Johnson, Director, Research Dept., Crucible Steel Co. of America; Mr. W. H. Phillips, R. D. Nuttall Co., Pittsburgh, Pa.; Dr. John S. Unger, Mgr., Central Research Bureau, Carnegie Steel Co., and the author.

On motion the meeting adjourned at 9:12 P. M.

K. F. TRESCHOW, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade, Tuesday, June 5, 1919, at 4:15 P. M., President George H. Neilson presiding, Messrs. Snyder, Hoerr, Hawley, Pittman, Frohrieb, Hunter, Schatz and the Secretary being present.

The Minutes of the last regular meeting held May 13th, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Bergen, George Thomas	Hecht, Max (A. C. S.)
Doane, N. D. (A.C.S.)	Kilgour, David
Fendner, Williard Julius	Marsland, Roland

Morgan, Harold H.

ASSOCIATE MEMBERS

Gibson, Robert McDowell	Polk, Robert Edmund

JUNIOR

Ritts, Arch Verral

The applications of the following gentlemen were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Ayres, Herbert S.	Johnson, Lane
Hanssen, John M.	Magaw, Harry Denny
Herper, Harry Conrad	Mumaw, John H.
Hermann, Theodore J.	Nichols, Fay Ira
Izod, Joseph Robert	Trayers, Edward B.

Ziegler, August

JUNIORS

Bercaw, Corliss Arthur	Klages, George Herbert
Bull, Harold W.	Logan, Harold Milton
Deist, Jay Wendell	Maurer, Rolland Edward
Eckert, Otto W.	Rieseck, Wilbert P.
Groseglas, A. C.	Simmons, Robert Humes
Jones, Arthur Edward	Squibb, Warner Spurgeon

Application for reinstatement was received from Joseph C. Utley and the Secretary was authorized to place his name on the Society Rolls and notify Mr. Utley to this effect.

Applications for transfer to higher grade of membership were received from the following gentlemen and the Secretary was authorized to make the transfer as follows:

Pyle, Clyde B. (Member) Spencer, Elbert R. (Member)

The Secretary presented letters of resignation from the following members and after discussion, they were ordered accepted:

Sherman, M. C. Todd, C. L.

The report of the Secretary showing the condition of the Society April 30, 1919, having been previously audited by the Finance Committee, was approved.

COMMITTEE REPORTS

Mr. Hawley, Chairman of the Entertainment Committee, reported that the Smoker held at the Ft. Pitt Hotel, May 17th, had a small attendance, probably on account of the strike of the street car employees. Attendance 48. Expenses were $276.20, and receipts $52.00, making a loss of $204.20. We expect to give a similar entertainment in the Fall. The Committee held one meeting during the past month and arrangements are complete for the Inspection Trip to Youngstown on Saturday, June 7th. Plans are under way for the steamboat excursion on the evening of June 19th.

Mr. Pittman, Chairman of the Finance Committee, reported that the Financial statement of the Secretary for April was checked and approved.

Mr. Schatz, Chairman of the House Committee, reported an evening attendance of 82 for the month of May as follows:

First week	22
Second week	16
Third week	17
Fourth week	19
First four days	8
	—
	82

Mr. Neilson read a letter received from Mr. Morris Knowles relative to a recent conference in Chicago under the auspices of the Engineering Council to assist in the establishment of a National Department of Public Works.

Mr. M. O. Leighton, Chairman of the Washington Executive Committee, Engineering Council, appointed Mr. Knowles a member of the Campaign Committee from Pennsylvania to organize the western part of Pennsylvania to assist in the legislation of the proposed plan when the time arrived.

Mr. Neilson stated that Mr. Knowles advised him over the 'phone that he felt the Engineers' Society should interest itself in the work.

After discussion, it was moved and carried that Mr. Knowles be appointed to represent the Engineers' Society in the matter and the Secretary was requested to notify him accordingly.

The meeting adjourned at 5:00 P. M.

K. F. Treschow, *Secretary.*

REGULAR MONTHLY MEETING

The 378th Regular Monthly Meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, June 3, 1919, at 8:15 P. M., President George H. Neilson presiding, 46 members and visitors being present.

The Minutes of the last regular meeting held May 20, 1919, were read and approved.

The Board of Direction reported the election of five applicants to the grade of Member, and three to the grade of Associate Member, the receipt of ten applications for membership; also two reinstatements and two applications for transfer to higher grade.

There being no further business before the Society, the paper of the evening on "Power Piping" was presented by Mr. J. Roy Tanner, Vice President and Gen. Mgr., Pittsburgh Valve Foundry & Construction Co., and Mr. George J. Stuart, Chief Engineer, of that company.

The ensuing discussion was participated in by: Mr. J. C. Hobbs, Asst. to Supt., Power Stations, Duquesne Light Co.; Mr. Harry Ottinger, Draftsman, National Tube Co., McKeesport, Pa.; Mr. H. K. Higgins, Asst. Engr., Aluminum Co. of America; Mr. H. W. Stevenson, Test Engr., Duquesne Light Co.; Mr. B. M. Herr, Dist. Sales Mgr., Edward Valve & Mfg. Co.; Mr. C. W. Crider, Boiler Room Supt., Duquesne Light Co.; Mr. Walter B. Spellmire, Mgr., General Electric Co.; Mr. P. W. Young, Duquesne Light Co., and the authors.

The meeting adjourned at 10:05 P. M.

K. F. Treschow, *Secretary.*

SPECIAL MEETING

A special meeting of the Engineers' Society of Western Pennsylvania was held in the Lecture Hall, Carnegie Library, Tuesday, July 1, 1919, at 8:15 P. M., President George H. Neilson presiding, 70 members and visitors being present.

The reading of the minutes of the last regular meeting held June 3, 1919, was dispensed with.

No further business coming before the Society, the paper of the evening was presented by Mr. N. S. Sprague, Chief Engineer, Bureau of Engineering, City of Pittsburgh, on the "Bond Issue and Subway."

The ensuing discussion was participated in by: Mr. Bankston, Chester & Fleming; Mr. George S. Davison, Pres., Gulf Refining Co.; Mr. Samuel E. Duff, Cons. Engr., Pittsburgh, Pa.; Mr. Edward Godfrey, Robt. W. Hunt & Co.; Mr. G. E. Flanagan, Mech. Engr., Heyl & Patterson, Inc., and the author.

On motion, a vote of thanks was extended to Mr. Sprague for his most interesting and instructive paper.

The meeting adjourned at 10:10 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, September 9, at 4:15 P. M. President George H. Neilson presiding, Messrs. Hawley, Danforth, Stucki, Barbour, Hunter, Spellmire, Minton and the Secretary being present.

The Minutes of the last regular meeting held June 5th were read and approved.

The application of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Ayres, Herbert S.
Hanssen, John M.
Herrman, Theodore J.
Herpel, Harry Conrad
Izod, Joseph Robert
Johnson, Lane
Magaw, Harry Denny
Mumaw, John H.
Nichols, Fay Ira
Trayers, Edward B.
Ziegler, August

JUNIORS

Bercaw, Corliss Arthur
Bull, Harold W.
Deist, Jay Wendell
Eckert, Otto W.
Grossglas, A. C.
Jones, Arthur Edward
Klages, George Herbert
Logan, Harold Milton
Maurer, Roland Edward
Rieseck, Wilbert P.
Simmons, Robert Humes
Squibb, Warner Spurgeon

The applications of the following gentlemen were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Adams, Frank Noble
Angle, James Macfarlane
Bathgate, O. H.
Drayer, Ulysses S.
Higgins, Herman K.
Hugo, Victor James
Paar, Oscar H.
Patterson, C. Thomas
Rahm, Edward, Jr.,
Stevenson, William Clarence

ASSOCIATE MEMBER

Huntsman, Roy C.

JUNIORS

Barton, Charles R.	Organ, Burford A.
Howell, Francis Kitchell	Smith, P. M.
McKee, William Johnston	Soule, Roe Thayer

The Secretary presented a list of Student Juniors and Juniors who have passed the age limit in their respective grades, some of whom have been notified two or three times that in accordance with the By-Laws, they would be obliged to apply for transfer. The Secretary was requested to make up a list of these names showing their present occupation and the amount of dues owing to the Society up to the present time, to be presented at the next meeting of the Board.

Applications for transfer were received from the following gentlemen and the Secretary was authorized to make the transfer to the following grades:

Anderson, John Kenneth	Member
Buente, William Harrison	Member
Day, Cecil Thurlow	Member
Davis, Philip Oudry	Associate Member
Richardson, Joseph G.	Member
Witte, Herman Calvert	Member
Lauer, William W.	Junior
Braun, Harry Shea	Junior

Letters of Resignation were presented by the Secretary from the following members, which after discussion were ordered accepted:

Doane, N. D.	Schneider, A. A.
Layton, Hudson F.	Schoepf, T. H.
Moore, Lee C.	Wilson, Henry M.

The Secretary presented a letter of resignation from Mr. C. W. Bretland, which after discussion was tabled and the Secretary requested to write him endeavoring to secure his consent to retain his membership in the Society as a non-resident member.

The Secretary reported the death of the following gentlemen:

	Joined	Died
Wm. A. Bole	May, 1884	June 16, 1919
Emil Swensson	April, 1887	May 13, 1919
R. C. Powell	Oct., 1913	

The Secretary was requested to secure a memoir from Mr. W. G. Wilkins of Mr. Bole and one of Mr. Swensson from Mr. George S. Davison.

The reports of the Secretary showing the condition of the Society at the close of business May 31, June 30 and July 31st respectively, having been regularly audited by the Finance Committee, were approved.

No written reports were presented by the Chairman of the various committees, owing to the fact that no meetings had been held during the summer months.

Mr. Neilson presented a communication in regard to the creating of a National Department of Public Works which included copy of Senate Bill No. 2232 defining its powers and duties.

After discussion it was moved and carried that this correspondence be turned over to the Civic Affairs Committee for their investigation, with the request that they report back to the Board at its next meeting.

Advertising contracts from the following firms were presented for approval and it was moved and carried that they be approved as written:

Steam Equipment & Mfg. Co.	½ page
Pgh. Des-Moines Steel Co.	½ page
Memphis Steel Const. Co.	½ page
McClintic-Marshall Co.	¼ page
W. E. Moore & Co.	⅛ page
A. S. Harr	½ page
Aluminum Co. of America	Back cover
Jeffrey Mfg. Co.	½ inside back cover
A. & B. Smith Co.	¼ page
The Foundation Co.	¼ page
Treadwell Engrg. Co.	½ page
B. K. Elliott Co.	1 page
General Electric Co.	Inside page

On motion the meeting adjourned at 5:15 P. M.

K. F. Treschow, *Secretary*.

SPECIAL MEETING

Board of Direction

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, September 15, at 4:00 P. M. President Neilson presiding, Messrs. Danforth, Stucki, Pittman, Hunter, Snyder, Hawley, Hoerr, Spellmire, Schatz and the Secretary being present. Mr. Morris Knowles, Chairman of the Special Committee on A National Department of Public Works, was also present.

Mr. Neilson stated that the meeting had been called to act on the report from Mr. Knowles, who was recently appointed to represent the Society on a committee organized by Engineering Council on the Establishment of a National Department of Public Works.

Mr. Neilson asked Mr. Knowles to advise the Board just what had been done and what action he thought should be taken. Mr. Knowles gave a detailed account of the work accomplished by the Committee up to the present time, stating that he had received a request for Pennsylvania to organize this district for the purpose of promoting the interests in the establishment of a National Department of Public Works and suggested that a special meeting of the Society be called at which Mr. M. O. Layton, Chairman of the Washington Executive Committee of Engineering Council be invited to speak; also that invitations for the meeting be sent to all organizations in this district who might be interested in this movement.

Mr. Knowles further stated that he would like to have his committee enlarged so as to secure a man from each of the surrounding districts to carry on the work in their territory.

It was moved and carried that the Secretary be authorized to call a special meeting of the Society for Tuesday, October 7th and that the entire arrangements for the meeting be put in the hands of the committee of which Mr. Knowles was chairman. It was further moved and carried that the President be authorized to enlarge the committee to not less than nine members, all of whom are to be appointed by the President.

The meeting adjourned at 5:00 P. M.

K. F. Treschow, *Secretary*.

REGULAR MONTHLY MEETING

The 379th Regular Monthly Meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, September 23, 1919, at 8:12 P. M. V. P. George H. Danforth presiding, 92 members and visitors being present.

The Minutes of the last regular meeting held June 3, 1919, and of the special meeting held July 1, 1919, were read and approved.

The Board of Direction reported the election of eleven applicants to the grade of Member and twelve to the grade of Junior and the receipt of seventeen applications for membership, five being received from the various National Society members. Also eight members transferred to higher grade.

Mr. Danforth called on Mr. Hiles to address the Society with a few minutes talk. Mr. Hiles stated that he was glad to get back to Pittsburgh to see all his old friends again, and that he often thought of the Engineers' Society while he was away. He also stated that the engineers had quite an interesting experience over there and quite a good deal of work.

No further business coming before the Society, the paper of the evening on "Safety and Welfare Work in Industrial Plants," was presented by Mr. H. A. Schultz, Asst. Manager, Safety Department, United States Steel Corporation, New York, N. Y.

The ensuing discussion was participated in by: Mr. A. R. Raymer, Asst. Chf. Engr., O. P. & L. E. R. R., Pittsburgh, Pa.; Mr. A. E. Crockett, Forging Engr., Jones & Laughlin Steel Co.; Mr. Joseph H. White, Morris Knowles Inc., Pittsburgh, Pa.

It was moved, seconded and carried that we extend to Mr. Schultz our appreciation of his interesting and instructive paper, also to the United States Steel Corporation for the use of the very entertaining films.

On motion the meeting adjourned at 10:40 P. M.

K. F. Treschow, *Secretary.*

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Thursday, October 2nd, at 4:15 P. M., President George H. Neilson presiding, Messrs. Danforth, Minton, Pittman, Schatz, Spellmire, Hunter and the Secretary being present.

The Minutes of the last regular meeting held September 9th, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society pursuant to the action of the Board, were elected to membership:

MEMBERS

Adams, Frank Noble	Hugo, Victor James
Angle, James Macfarlane	Paar, Oscar H.
Bathgate, O. H.	Patterson, C. Thomas
Drayer, Ulysses S.	Rahm, Edward, Jr.
Higgins, Herman K.	Stevenson, William Clarence

ASSOCIATE MEMBER

Huntsman, Roy C.

JUNIORS

Barton, Charles R.	Organ, Burford A.
Howell, Francis Kitchell	Smith, P. M.
McKee, William Johnston	Soule, Roe Thayer

The applications of the following gentlemen were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Forman, William Heamsley	Uhl, Elmer Jenemiah

The Secretary presented a list of Juniors and Student Juniors who should be transferred to higher grades of membership in accordance with Sections 7 and 8 of Article 1, who were automatically transferred.

Application for transfer to higher grade was also received from Mr. V. B. Edwards, who after discussion was transferred to the grade of member.

Mr. Danforth, Chairman of the Civic Affairs Committee, stated that the matter of Senate Bill No. 2232, Department of Public Works, which was referred to the Civic Affairs Committee, at the last meeting, had since been a matter of consideration by the Board at a special meeting, and the committee had no report to make.

In the absence of Mr. Hawley, Chairman of the Entertainment Committee, the Secretary reported verbally stating that the committee were making arrangements for our Annual Banquet, which will probably be held early in December.

Mr. Pittman, Chairman of the Finance Committee, stated that the Financial statements for May, June, July and August had been checked and approved since the last report of the Finance Committee.

Ernst & Ernst have made their annual audit of the books covering the year ending June 30, 1919, and have submitted to us a comprehensive and lucid report. They compliment us on our clear and carefully kept records.

The auditors advise us that the market value of our bonds has increased.

Due to the unremitting efforts of our Secretary in making collections, the loss last year from unpaid accounts was only about one-third the amount for the previous year.

Mr. Schatz, Chairman of the House Committee, reported verbally stating that the committee had a matter up regarding change in the Society quarters, as the first period of our lease expires May 1, 1920. He stated that he expected to hold a meeting of the committee in the near future, at which time the matter would be taken up and discussed and suggested plans made ready for the Board at its next meeting.

Mr. Spellmire, Chairman of the Publication Committee, reported that a tentative program as laid out early in the season gave fair promise of being carried out as planned.

The reports of the Secretary showing the condition of the Society at the close of business August 31st, having been regularly audited by the Finance Committee, was approved.

The meeting adjourned at 5:00 P. M.

K. F. TRESCHOW, Secretary.

SPECIAL MEETING

A special meeting of the Engineers' Society of Western Pennsylvania was held at Carnegie Lecture Hall, Tuesday, October 7th, at 8:15 P. M., President George H. Neilson presiding, 40 members and visitors being present.

The meeting was called for the discussion of a proposed bill creating a National Department of Public Works, and a paper on the subject was presented by Mr. M. O. Leighton, Chairman, National Service Committee of the Engineering Council, Washington, D. C.

Written discussion was received from Mr. Samuel E. Duff, Consulting Engineer, Pittsburgh, Pa.

The ensuing discussion was participated in by: Mr. George H. Neilson, V. P., Braeburn Steel Co., Braeburn, Pa.; Mr. John N. Chester, Chester & Fleming, Pittsburgh, Pa.; Mr. J. G. Chalfant, County Engr., Allegheny County; Mr. Morris Knowles, Cons. Engr., Pittsburgh, Pa.; Mr. George S. Davison, Pres., Gulf Refining Co.; Mr. N. S. Sprague, Chf. Engr., Bureau of Engineering, City of Pittsburgh; Mr. W. E. Snyder, Mech. Engr., American Steel & Wire Co., and the author.

It was moved and carried unanimously that the meeting endorse the bill as presented by Congress and that such endorsement be certified to the Conference.

It was also moved and carried that a vote of thanks be tendered Mr. Leighton for his very interesting paper.

The meeting adjourned at 9:49 P. M.

K. F. TRESCHOW, Secretary.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, October 14th, at 8:15 P. M., Chairman L. C. Frohrieb presiding, 52 members and visitors being present.

The Minutes of the last meeting held March 25th, were read and approved.

No further business coming before the Section, the paper of the evening on "Notes on Bronze and Babbitt Bearings" was presented by Mr. W. K. Frank, V. P. and Gen. Mgr., Damascus Bronze Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: Mr. M. P. Clark, Eng., National Tube Co.; Md. H. A. E. Howarth, Associate; Albert Kingsbury, Consulting Engineer; Dr. John S. Unger, Mgr., Central Research Bureau, Carnegie Steel Co.; Mr. T. D. Lynch, Research Engr., Westinghouse Elec. & Mfg. Co.; Mr. A. C. Stalknecht, Proprietor, U. S. A. Grease Company; Mr. Joe. Slutzker, M. M., Pennsylvania R. R. Co., and the author.

On motion the meeting adjourned at 10:15 P. M.

K. F. TRESCHOW, Secretary.

REGULAR MONTHLY MEETING

The 380th Regular Monthly Meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, October 21, 1919, at 8:15 P. M., Mr. E. D. Leland presiding, in the absence of the President and both Vice Presidents, 127 members and visitors being present.

The Minutes of the last regular meeting held September 23rd and of the special meeting held October 7th, were read and approved.

The Board of Direction reported the election of 17 applicants to merbership, ten to the grade of Member, one to the grade of Associate Member and six to the grade of Junior. Also the receipt of two applications for membership and one for transfer to higher grade. There were automatically transferred four Student Juniors to the grade of Member and four to the grade of Junior, and twenty-seven Juniors to the grade of Member.

No further business coming before the Society, the paper of the evening on "Post War Conditions in Europe, With Some Comparisons of European and American By-Product Coke-Oven Products" was presented by J. I. Thompson, Chief Engineer, The Koppers Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: Mr. A. C. Fieldner, Chemist, U. S. Bureau of Mines; Mr. C. W. Littler, Chf. Engr., Clairton By-Products Coke Works, Clairton, Pa.; Mr. James D. Miller, Student, Carnegie Inst. of Technology; Mr. J. J. Wilson, National Tube Co., McKeesport, Pa., and the author.

On motion the meeting adjourned at 9:30 P. M.

K. F. TRESCHOW, Secretary.

METALLURGICAL & MINING SECTION

The Regular Bi-Monthly Meeting of the Metallurgical & Mining Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Adcade Building, Tuesday, October 28th, at 8:15 P. M., Dr. John S. Unger presiding, 32 members and visitors being present.

The Minutes of the last meeting held March 25th, were read and approved.

No further business coming before the Section, the paper of the evening on "Industrial Applications of Nickel Chromium Alloys" was presented by Mr. W. A. Catward, Engineer, Hoskins Mfg. Co., Detroit, Mich.

The ensuing discussion was participated in by: Mr. S. K. Katz, Chemist, U. S. Bureau of Mines; Dr. John S. Unger, Mgr., Central Research Bureau, Carnegie Steel Co.; Mr. P. H. Brace, Engr., Research Division, Westinghouse Elec. & Mfg. Co.; Mr. W. I. Sivitz, Chemist, Aluminum Co. of America; Mr. C. E. Skinner, Engr., Research Division, Westinghouse Elec. & Mfg. Co., and the author.

It was moved, seconded and carried unanimously that a vote of thanks be given to Mr. Catward for his very excellent and admirable paper.

On motion the meeting adjourned at 9:35 P. M.

K. F. TRESCHOW, Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Thursday, November 7, at 4:15 P. M., President George H. Neilson presiding, Messrs. Hoerr, Hunter, Spellmire, Danforth, Schatz, Stucki, Minton, Barbour and Hawley being present, Mr. Danforth acting as Secretary in Mr. Treschow's absence.

The minutes of the last regular meeting, held October 2, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Uhl, Elmer J. Forman, William H.

The applications of the following gentlemen were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

MEMBERS

Beringer, Edward Warren
Pearsall, Luther T.
Milliken, James
Stoltz, Glenn Edwin
Thompson, John I.

ASSOCIATE MEMBERS

Schroeder, Frank Conrad
James, Mark S.

JUNIORS

Baker, Donald J.

Application for membership was received from Paul C. Merz, and was ordered held over until the next meeting of the Board.

Request for reinstatement was received from Mr. A. D. Neal and the Board requested that a letter be written Mr. Neal, asking that he fill out and send in another application, as his first application was not acted upon on account of his withdrawing it before election, and the Board could not reinstate him, as he had never been elected.

Applications for transfer to higher grade were presented by the following gentlemen, and after discussion the Board requested that they be transferred to the grade of Member:

Church, Walter S.
Hugins, Charles B.
Smith, Rupert V.

Mr. H. M. Cooley asked that he be placed in the Student Junior class, as he was not at present working, but was a student at Carnegie Institute of Technology. The Board requested that the Secretary write Mr. Cooley stating that he had been transferred to Student Junior.

Letters of resignation were received from the following gentlemen, which, after discussion, were ordered accepted:

Cross, Lloyd A.	Joined	Oct., 1915
Edge, Dexter	"	Apr., 1918
Hall, R. Dawson	"	Oct., 1913
Hislop, W. A.	"	June, 1914
Kaufman, E.	"	May, 1902
Raisig, C. L.	"	May, 1913
Rowe, W. A.	"	Dec., 1913
Uptegraff, R. E.	"	June, 1918

The Acting Secretary reported the death of Mr. David Hunter, Jr., who joined the Society April, 1898, and died November 3, 1919.

The report of the Secretary showing the condition of the Society at the close of business September 30, 1919, having been regularly audited by the Finance Committee, was approved.

Mr. Danforth, Chairman of the Civic Affairs Committee, reported verbally, stating that contract had been awarded for the design and supervision of the Sixteenth and Fortieth Street Bridges to architectural firms. There was considerable discussion, and the matter was referred back to the Committee to make a report at the next meeting of the Board.

Mr. Hawley, Chairman of the Entertainment Committee, reported that the Committee had called a meeting and discussed the question of the annual dinner, proposed inspection trips and a smoker.

He also stated that it was impossible, under conditions existing, to arrange for inspection trips, and that several which we had under consideration had to be called off or postponed.

Arrangements are also being made for an entertainment, combining a luncheon with moving pictures. Ladies will be invited, and it has been planned to have dancing. The entertainment will be held at the Fort Pitt Hotel on November 15.

Mr. Hawley also advised that efforts to secure speakers for the annual dinner early in December had been unsuccessful and plans were being made to hold the dinner in January. We have tentative promises from some eminent speakers, and definite arrangements and announcements will be made as soon as possible.

Mr. Schatz, Chairman of the House Committee, reported an evening attendance for October as follows: First week, 6; second week, 2; third week, 7; fourth week, 6; last five days, 4. Total, 25.

He also reported verbally stating that he thought it necessary that the Secretary obtain help to fix up the storage space, which was authorized by the Board.

He also stated that there may be some changes made to allow us space and auditorium on the tenth or eleventh floors.

Mr. Barbour, Chairman of the Membership Committee, reported progress.

Mr. Spellmire, Chairman of the Publication Committee, reported that the program as tentatively prepared early in the season gives fair promise of being carried out as planned.

The Nominating Committee presented the following report:

Pittsburgh, Pa., November 4, 1919.

To the Board of Direction,
Engineers' Society of Western Pennsylvania.

Dear Sirs::

At a meeting of the Nominating Committee of the Engineers' Society of Western Pennsylvania, held in the Society Rooms, Tuesday, November 4, the following gentlemen were chosen unanimously for the respective offices indicated below:

For President	W. C. Hawley
For Vice President	H. D. James
For Treasurer	A. Stucki
For Directors	J. H. Minton W. E. Fohl

Respectfully submitted,
NOMINATNIG COMMITTEE,
Frederic Crabtree, Chairman;
S. A. Taylor,
M. F. Newman,
James O. Handy,
W. B. Spellmire.

It was moved and carried that the nominations be approved and the names published to the Society in accordance with Laws.

A letter was received from Mr. Samuel E. Duff and aroused some very interesting discussion.

On motion, the meeting adjourned at 5:16 P. M.

K. F. TRESCHOW, *Secretary.*

REGULAR MONTHLY MEETING

The 381st regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, November 18, at 8:20 P. M., President George H. Neilson presiding, 39 members and visitors being present.

The minutes of the last regular meeting, held October 21, were read and approved.

The Board of Direction reported the election of two applicants to the grade of Member and the receipt of eight applications for membership. Also one application for reinstatement and three for transfer to higher grade.

No further business coming before the Society, the paper of the evening was presented by Mr. E. M. Kinney, General Engineering Laboratory, General Electric Co., Schenectady, N. Y.

The ensuing discussion was participated in by: Mr. S. M. Kintner, V. P. and Gen. Mgr., International Radio Telegraph Co., Pittsburgh, Pa.; Mr. J. B. Mandeville, Chf. Engr., T. W. Phillips Gas & Oil Co., Butler, Pa.; and the author.

It was moved, seconded and carried unanimously that a vote of thanks be extended to Mr. Kinney for his very interesting and instructive paper.

On motion, the meeting adjourned at 10:45 P. M.

K. F. TRESCHOW, *Secretary.*

CIVIL SECTION

The regular bi-monthly meeting of the Civil Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, November 11, at 8:17 P. M., Chairman J H. Minton presiding, 58 members and visitors being present.

The minutes of the last regular meeting, held May 6, were read and approved.

No further business coming before the Section, the paper of the evening, on "Roofing Materials for Industrial Plants," was presented by Mr. M. Davis, Manager, H. H. Robertson Co., Pittsburgh, Pa.

The ensuing discussion was participated in by: David Elder, Mech. Engr., Equitable Gas Co.; A. J. White, Mgr., Cement Gun Const. Co.; W. R. Frazier, Mgr. Pittsburgh Sales Dept., H. H. Robertson Co.; J. B. Walker, Secy. & Treas., Pittsburgh Heating Co.; J. deS. Freund, Secy. &

Gen. Mgr., American Cement Tile Co.; W. R. Persons, Asst. Supt., Diamond Alkali Co., Painesville, O.; C. N. Haggart, 323 Fourth Ave., Pittsburgh, Pa.; H. T. Darlington, Pennsylvania Salt Mfg. Co., Wyandotte, Mich.; J. H. Minton, Asst. to Gen. Mgr., Carnegie Steel Limestone Co.; J. E. Webster, Westinghouse Elec. & Mfg. Co.; B. A. Ludgate, Asst. Engr., P. & L. E. R. R. Co.; A. E. Blake, Sales Engr., Surface Combustion Co.; C. T. Day, Detailer, American Bridge Co.; and the author.

It was moved, seconded and carried unanimously that a vote of thanks be extended to Mr. Davis for his very excellent paper.

On motion, the meeting adjourned at 10:15 P. M.

K. F. Treschow, *Secretary*.

METALLURGICAL AND MINING SECTION

The regular bi-monthly meeting of the Metallurgical and Mining Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, November 25, at 8:20 P. M., Chairman J. S. Unger presiding, 59 members and visitors being present.

The minutes of the last meeting, held October 28, were read and approved.

No further business coming before the Section, the paper of the evening, on "New Developments in Acid Resisting and Cutting Alloys," by Mr. Ellwood Haynes, President, Haynes Stellite Co., Kokomo, Ind., was presented.

The ensuing discussion was participated in by: Dr. John S. Unger, Mgr., Central Research Bureau, Carnegie Steel Co.; Philo Kemery, Supt., Open Hearth and Crucible Furnaces, Crucible Steel Co. of America; D. H. Horne, Special Representative, Standard Alloys Company; E. D. Leland, Supt., Compressing Stations, Philadelphia Co.; G. L. Kronfeld, Vulcan Crucible Steel Co.; Paul E. Demmler, Chem. Engr., Westinghouse Elec. & Mfg. Co.; Webster Tallmadge, Mech. Engr., Service Dept., Westinghouse Elec. & Mfg. Co.; Wm. J. Merten, Research Engr., Westinghouse Elec. & Mfg. Co.; V. C. Allison, Chemist, U. S. Bureau of Mines; and the author.

It was moved, seconded and carried unanimously that a vote of thanks be extended to Mr. Haynes for his very excellent paper.

On motion, the meeting adjourned at 9:25 P. M.

K. F. Treschow, *Secretary*.

MECHANICAL SECTION

The regular bi-monthly meeting of the Mechanical Section of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, December 2nd, at 8:10 P. M., Chairman L. C. Frohrieb presiding, 78 members and visitors being present.

The minutes of the last meeting held October 14th, were read and approved.

No further business coming before the Section, the paper of the evening on "Superheaters and the Utilization of Superheated Steam" was presented by Messrs. D. D. Pendleton and C. A. Brandt, Industrial Department, Locomotive Superheater Co., Pittsburgh, Pa.

Written discussion was received from: Mr. W. E. Snyder, Mech. Engr., American Steel & Wire Co.; Mr. John Primrose, Chf. Engr., Power Specialty Co., New York, N. Y.; Mr. F. M. VanDeventer, National Tube Co.

The ensuing discussion was participated in by: Mr. W. N. Flanagan· Steam Engr., Ohio Works, Carnegie Steel Co., Youngstown, O.; Mr. G. D, Bradshaw, Dravo Superheater Co.; Mr. Max Hecht, Chemist, Duquesne Light Co.; Mr. W. P. Chandler, Asst. Expr. Engr., Carnegie Steel Co., Duquesne, Pa.; Mr. G. C. Bell, West Penn Railways Co.; and the authors.

Under the By Laws, Mr. Pendleton, as a member, cannot be given a vote of thanks. It was moved, seconded and carried unanimously to extend to Mr. Brandt our appreciation of the paper.

On motion the meeting adjourned at 10:33 P. M.

K. F. Treschow,

Secretary.

BOARD OF DIRECTION

The regular monthly meeting of the Board of Direction of the Engineers Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Thursday, December 4th, at 4:10 P. M., President George H. Neilson presiding, Messrs. Minton, Schatz, Hoerr, Hawley, Pittman, Frohrieb and the Secretary being present.

The Minutes of the last regular meeting held November 7th, were read and approved.

The applications of the following gentlemen, having been regularly published to the Society, pursuant to the action of the Board, were elected to membership:

MEMBERS

Beringer, Edward Warren — Pearsall, Luther T.
Milliken, James — Stoltz, Glenn Edwin
Thompson, John I.

ASSOCIATE MEMBERS

Schroeder, Frank Conrad — James, Mark S.

JUNIOR

Baker, Donald J.

The applications of the following gentlemen were received and their names ordered published to the Society. Assignment to the various grades of membership is as follows:

JUNIORS

Templin, Richard L. — Thorn, Thomas H.

Request for reinstatement was received from Mr. W. C. Rott, and the Board requested that a letter be written Mr. Rott, stating that his name had been placed on the Society Rolls.

Applications for transfer to higher grade were received from the following gentlemen, and after discussion, the Board requested that they be transferred to the grade of Member.

Barton, Charles Raymond — Robinson, James Wilson

Letters of Resignation were received from the following gentlemen, which after discussion, were ordered accepted.

Eisenberg, B. D. — Morrison, W. P.
Ericson, E. G. — Tayman, G. L.

The report of the Secretary showing the condition of the Society at the close of business October 31, 1919, having been regularly audited by the Finance Committee, was approved.

Committee Reports

In the absence of Mr. Danforth, Chairman of the Civic Affairs Committee, the Secretary made a verbal report stating that Mr. Danforth had considered the matter referred to the Committee at the last meeting of the Board in regard to the awarding of the bridge contract to architects and suggested that the Board write the County Commissioners, protesting against the action taken.

It was moved and carried that the Board instruct the Civic Affairs Committee to draw up a resolution to be approved by the Board at a special meeting to be held on Tuesday evening, December 16th, at 7:00 o'clock; the resolution to be presented before the meeting of the General Society to be held the same evening.

The Board further requested the Chairman to have this resolution prepared in time for the Secretary to make copies to be sent to each member of the Board not later than Friday, December 12th; also that the Secretary be instructed to insert a notice in the regular announcement for the December 16th meeting, calling attention to the fact that this matter would be taken up as special business at this meeting and that copies of the special notice be sent to each County Commissioner elect inviting them to attend the meeting.

Mr. W. C. Hawley, Chairman of the Entertainment Committee, reported that the Committee had not held any meeting during the month of November but had been busy planning for the Annual Dinner to be held January 26th.

The Entertainment in the English Room of the Ft. Pitt Hotel, November 8th, had an attendance of a little more than a hundred and was thoroughly enjoyed by those present. The total expenses were $000.00 and the total receipts $151.50.

Mr. Pittman, Chairman of the Finance Committee, reported that the Secretary's reports for the months of September and October had been checked and approved.

Mr. Schatz, Chairman of the House Committee, reported an evening attendance of 19 for the month of November as follows:

First week	14
Second week	4
Third week	0
Fourth week	1
	19

He reported verbally stating that the Committee had taken up the matter of placing the magazines on the Library Tables in a magazine rack, such as is used by a number of Clubs and stores. It was pointed out that the magazines as kept at present became very dusty and it was almost impossible to keep the tables in an orderly condition. The Committee has considered making these racks about 4 feet in length with two cases and is planning a space for them in the Library.

After discussion it was moved and carried that the House Committee be be authorized to purchase these racks.

In the absence of the Chairman of the Publication Committee, Mr. Spellmire, the Secretary reported verbally stating that the program for the remainder of this year gave promise of being carried out as originally planned.

The Secretary read a letter from Mr. H. W. D. English to the effect that Councils at the present time are working on the Budget for the coming year and it was suggested that their attention be called to Westinghouse Memorial Park, with the suggestion that they set aside an appropriate amount for putting it in shape and the up-keep of the Park.

After discussion it was moved and carried that the President and Secretary be instructed to communicate with Council, suggesting that an appropriate amount for this work be allowed for in the Budget for 1920. The Secretary was further requested to acknowledge Mr. English's letter stating that the Board had written Council calling their attention to this matter and thank him for his interest.

Mr. Neilson presented and read a letter received from Mr. C. D. Armstrong, President Citizens Committee, City Plan of Pittsburgh. After discussion it was moved and carried that a letter be referred to the Civic Affairs Committee and the Secretary requested to write Mr. Armstrong to this effect.

Nominations. In accordance with Section 7, Article 5 of the By Laws, the Board finally passed upon the eligibility of the nominees selected for the coming year and the Secretary was requested to print the ballots as set forth in this section.

The meeting adjourned at 5:40 P. M.

K. F. TRESCHOW,
Secretary.

SPECIAL MEETING
BOARD OF DIRECTION

A special meeting of the Board of Direction of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, June 16th, at 7:06 P. M., President George H. Neilson presiding, Messrs. Pittman, Spellmire, Schatz, Stucki, Hawley, and Danforth being present.

The meeting was called to take up the matter of a resolution prepared by the Civic Affairs Committee on the question of the Awarding of the contract for the 16th and 43d Street Bridges to architectural firms and the following resolution was submitted by Mr. Danforth, Chairman:

Whereas: The County Commissioners of Allegheny County have retained architectural firms to design and superintend the construction of the new bridges at 16th and 43rd Streets, and

Whereas: The design and superintendence of such bridges are essentially engineering and not architectural in character.

Therefore Be It Resolved, by the Engineers' Society of Western Pennsylvania, an engineering association of over 1200 members that such award is not in accord with the best interest of the Community and that protest be made to the County Commissioners of Allegheny County on account of said award and that they be requested to revoke these commissions and transfer them to Consulting Engineers qualified by study and experience to handle such work.

After discussion it was moved, seconded and carried that the resolution be adopted and presented before the General Society meeting to be held the same evening.

On motion the meeting adjourned at 7:56 P. M.

K. F. TRESCHOW,
Secretary.

REGULAR MONTHLY MEETING

The 382nd regular monthly meeting of the Engineers' Society of Western Pennsylvania was held in the Society Rooms, Union Arcade Building, Tuesday, December 16th, at 8:10 P. M., President George H. Neilson presiding, 69 members and visitors being present.

The Minutes of the last regular meeting held November 18th were read and approved.

The Board of Direction reported the election of five applicants to the grade of Member, two to the grade of Associate Member and one to the grade of Junior, and the receipt of two applications for membership; one reinstatement and two transfers to higher grade.

The Civic Affairs Committee presented for the consideration of the Society the following Resolution by Mr. George H. Danforth, Chairman, notice of its presentation having been given to the Society.

WHEREAS, The County Commissioners of Allegheny County have retained architectural firms to design and superintend the construction of the new bridges at 16th and 43rd Streets, and

WHEREAS: The design and superintendence of such bridges are essentially engineering and not architectural in character.

THEREFORE BE IT RESOLVED, By the Engineers' Society of Western Pennsylvania, and engineering association of over 1200 members, that such award is not in accord with the best interests of the Community and that protest be made to the County Commissioners of Allegheny County on account of said award and that they be requested to revoke the commissions and transfer them to Consulting Engineers qualified by study and experience to handle such work.

After considerable discussion, it was moved by Mr. Rice that the resolution be referred back to the committee for modification, which motion was seconded and carried.

There being no further business before the Society, the paper of the evening on "Electrically Operated Gate Valves" was presented by Mr. Peter P. Dean, Cutler Hammer Mfg. Co., New York, N. Y.

The ensuing discussion was participated in by: Mr. B. M. Herr, Dist. Sales Mgr., Edward Valve & Mfg. Co.; Mr. J. G. Stuart, Chf. Engr., Pittsburgh Valve Fdry. & Const. Co.; Mr. W. C. Hawley, Chf. Engr. & Gen.

Supt., Pennsylvania Water Co., Wilkinsburg, Pa.; Mr. M. W. Link, Designing Engr., The Crane Co., Chicago, Ill.; Mr. Walter B. Spellmire, Gen Mgr., General Electric Co; and the author.

On motion duly seconded and carried, a vote of thanks was extended to Mr. Dean for his very excellent paper.

On motion the meeting adjourned at 10:10 P. M.

K. F. TRESCHOW,
Secretary.

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INCORPORATED 1880

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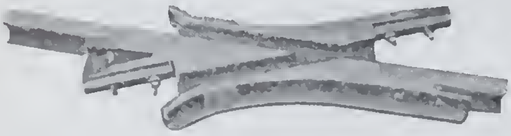

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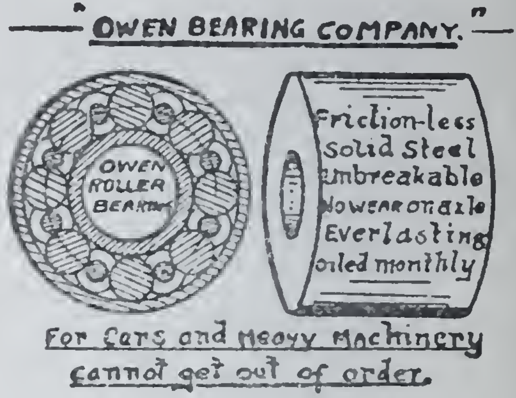

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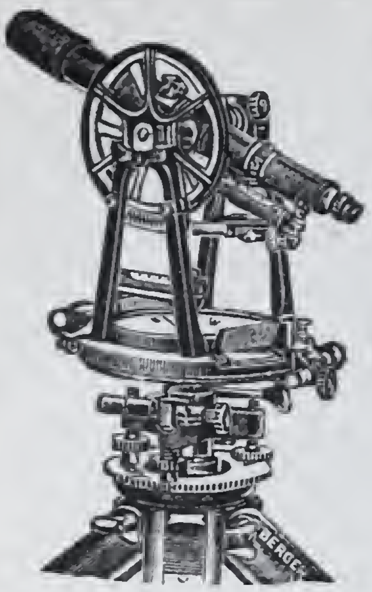

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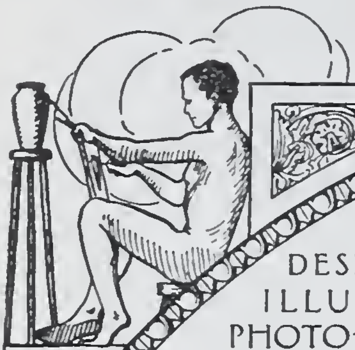

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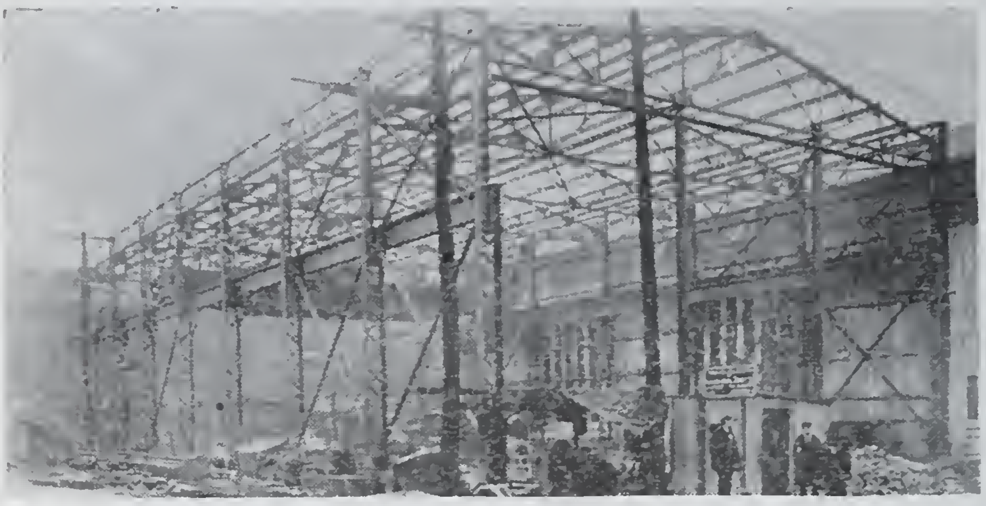

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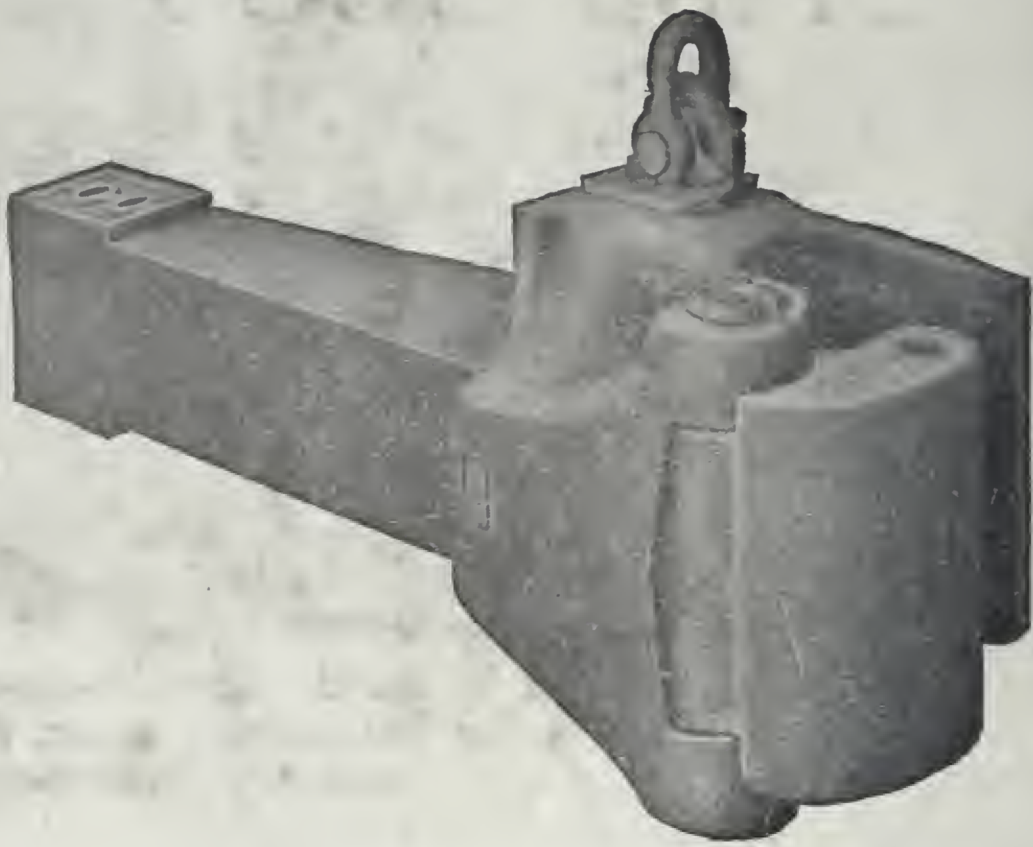

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